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Tribute to Ed Voss

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EDWARD G. VOSS (1929–2012)

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Edward Groesbeck Voss (Fig. 1), Professor and Curator Emeritus at the University of Michigan Department of Ecology and Evolutionary Biology and University of Michigan Herbarium, died on February 13, 2012 at his home in Ann Arbor, after a brief illness. He was born on February 22, 1929 in Delaware, Ohio. Ed's abilities were clear early in his life. He attended Woodward High School in Toledo, Ohio. He received the Achievement Award as the outstanding senior in his 1946 high school class, and was later elected to the Woodward High Hall of Fame. He then graduated with a bachelor's degree with honors from Denison University (1950); his undergraduate honors thesis, *On the classification of the Hesperiidae*, became a significant paper on Lepidoptera (Voss 1952). He completed his education with a master's in Biology (1951) and a doctoral degree in Botany (1954), both from the University of Michigan working with Rogers McVaugh. He was awarded an honorary Doctor of Science from Denison University in 2003.

In 1956, he began his long association with the University of Michigan and Michigan's flora when he was appointed as a research associate at the Herbarium, beginning what was expected to be a five-year project to document the flora of Michigan. He joined the Botany faculty in 1960 as assistant professor and was promoted to associate professor (1963), and later, professor (1969). He continued his painstakingly precise study of the flora of Michigan, culminating 40 years later with the publication of the third volume of the Michigan Flora in 1996; the same year that he retired and was granted Professor Emeritus status. He also served as Curator of Vascular Plants at the Herbarium from 1961 until his retirement in 1996 and continued to work at the herbarium until late in 2011.

Ed's research focused on the vascular plants of the Great Lakes region: their taxonomy, phytogeography, and status in natural environments; with a particular interest in boreal plants and aquatic plants. He maintained a small herbarium at his cottage in Mackinaw City, but most of his collections went to the University of Michigan Herbarium, with modest numbers also helping to build up the Biological Station herbarium. Ed founded and edited the first 15 volumes of *The Michigan Botanist* and served on the Editorial Board until his death.

Ed also continued his early interest in Lepidoptera throughout his life. He collected and studied them extensively, publishing a number of articles on the Lepidoptera of the Douglas Lake region (Emmet and Cheboygan counties). He was honored in 2011 as a founding member of the Lepidopterists' Society.

Coincident with his floristic research, Ed was a long time instructor at The University of Michigan Biological Station (UMBS). Ed began at the station in

FIGURE 1. Ed Voss beloved friend, mentor, teacher, and colleague. Photo by John Russell.

1949 as a teaching assistant for Rogers McVaugh; during the next several summers he assisted in courses taught by Carroll Wood, Lloyd Shinners,[1] and Elzada Clover. From 1963 to 2003 (missing only 1975 and 1999–2002), Ed taught Aquatic Flowering Plants (Fig. 2), Taxonomy of Flowering Plants, Boreal Flora, and Field Botany of Northern Michigan at the Station. He continued teaching "minicourses" through 2009. He was honored at the Station by a special "Dr. Edward Voss Celebration" Weekend in 2009. Ed had received an early introduction to the station when his parents took Ed, then 9 years old, to a "Visitor's Day" at UMBS. On the Ann Arbor campus, Ed taught Aquatic Flowering Plants, from 1961–93, Writing for Biologists in 1987, 1988, 1990, and 1992, and as one of the instructors in the Plant Biology course from 1974–79. Post-retirement, Ed taught popular courses and led field trips through the Adult Education Program of the Matthaei Botanical Gardens and workshops in the Upper Peninsula on aquatic plants, general plant identification, and boreal flora for Forest Service personnel and other people working with stewardship.

Ed gave long service to plant nomenclature via membership on the General and Editorial Committees responsible for the revision of the International Code of Botanical Nomenclature. He was a member of the Editorial Committee from 1969 to 1993 (i.e. from the Seattle to the Berlin Codes), served as the Secretary

[1]See Rabeler & Reznicek, 2012. J. Bot. Res. Inst. Texas 6: 311–312.

FIGURE 2. Ed Voss with his Aquatic Flowering Plants class in 1965. Photo by John Russell.

of the Committee for the Seattle and Leningrad Codes, and Chair for the Sydney Code.[2]

The first volume of *Michigan Flora* was honored by a Resolution of the Michigan Senate in 1972, while the second volume received the H.A. Gleason Award from the New York Botanical Garden in 1986. The Michigan Botanical Club also presented a lifetime achievement award to Ed in 1998, following publication of the final volume of *Michigan Flora* in 1996.

He was devoted to the conservation of natural areas, and served two terms as a member of the Board of Trustees of the Nature Conservancy of Michigan and was a long time Trustee of the Little Traverse Conservancy. He served on a number of citizens advisory committees for environmental stewardship and also served on the Technical Advisory Committee for Plants for the Michigan Threatened & Endangered Species Program and was a member of the equivalent committee for Ohio. Throughout all this service, he worked to educate others around him, always concerned that the information about the flora being used in decision making was as accurate as possible.

He was well known to students, professionals, and amateurs alike, sharing his passion for botany equally with all. His precision, wit (often as clever puns), command of the English language, and propensity for being thrifty all added up to make him "Ed"—a unique man who left his mark on the study of the Michigan flora and nomenclature alike.

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[2] See: Rabeler & Reznicek, 2012. Taxon 61: 697.

As a tribute to Ed and his work on the plants of Michigan, we present a series of invited papers that we hope will give more insight into the various "sides" of Ed, as well as basic biographical data including a hopefully complete bibliography, eponymy, list of new combinations and names resulting from Ed's research, plus a list of graduate students whose committee Ed chaired or co-chaired.

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This bibliography is split into three parts: Ed's formal publications, his *Michigan Plants in Print* series, and his numerous book reviews. Items in the formal bibliography are listed by the actual date published, even if the date printed on the publication differs. For the *Michigan Plants in Print* and book reviews, the date printed in the journal is accepted. Numerous ephemeral items, such as his many pungent "Letters to the Editor" to newspapers and journals, as well as editorial notices and other such items in *The Michigan Botanist,* are not included.

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MICHIGAN PLANTS IN PRINT

Between the inception of *The Michigan Botanist*, and the publication of Volume 3 of Michigan Flora (Voss, 1996), Ed contributed this series to the Journal, referencing all journal articles, books and other references of which he was aware that were about Michigan plants or had a bearing on the occurrence and distribution of plants in the State, including maps, biographies, and other useful materials. Before the easy digital availability of literature and the ability to search large scholarly databases, this byproduct of Ed's research on the Michigan Flora provided students and other researchers with an unparalleled access to relevant literature on Michigan plants.

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NEW NAMES AND COMBINATIONS

The following list of new names and combinations which Ed Voss authored is arranged alphabetically by genus. The dates given are as recorded in the International Plant Name Index (IPNI).

Acer saccharum Marshall var. *viride* (Schmidt) E. G. Voss. Michigan Bot. 24: 122. 1985.
Agropyron dasystachyum (Hook.) Scribn. var. *psammophilum* (J. M. Gillett & H. Senn) E. G. Voss. Rhodora 68: 437. 1966.
Agrostis hyemalis (Walter) Britton, Sterns & Poggenb. f. *setigera* (Fernald) E. G. Voss. Rhodora 68: 438. 1966.
Bidens connata Willd. f. *ambiversa* (Fassett) E. G. Voss. Michigan Bot. 34: 139. [Dec 1996] "October, 1995"
Bidens connata Willd. f. *anomala* (Farw.) E. G. Voss. Michigan Bot. 34: 139. [Dec 1996] "October, 1995"
Bromus pubescens Spreng. f. *glabriflorus* (Wiegand) E. G. Voss. Rhodora 68: 440. 1966.
Carex communis L.H. Bailey f. *gynandra* (Farw.) E. G. Voss. Rhodora 68: 451. 1966.
Carex rugosperma Mack. var. *tonsa* (Fernald) E. G. Voss. Rhodora 68: 453. 1966.
Cirsium hillii (Canby) Fernald f. *albiflorum* E. G. Voss. Michigan Bot. 34: 139. [Dec 1996] "October, 1995"
Cirsium pitcheri Torr. & A.Gray f. *magenteum* E. G. Voss. Contr. Univ. Michigan Herb. 23: 350. 2001.
Liatris scariosa (L.) Willd. var. *nieuwlandii* (Lunell) E. G. Voss. Michigan Bot. 34: 139. [Dec 1996] "October, 1995"
Nuphar variegata Durand f. *lutescens* (Farw.) E. G. Voss. Michigan Bot. 24: 120. 1985.
Orchis rotundifolia Pursh f. *lineata* (Mousley) E. G. Voss. Rhodora 68: 462. 1966.
Polygala polygama Walter f. *ramulosa* (Farw.) E. G. Voss. Michigan Bot. 24: 121. 1985.
Puccinellia fernaldii (Hitchc.) E. G. Voss. Rhodora 68: 445. 1966.
Salix exigua Nutt. f. *wheeleri* (Rowlee) E. G. Voss. Michigan Bot. 24: 117. 1985.

Salix glaucophylloides Fernald var. *brevifolia* (C. F. Wheeler & E. F. Sm.) C. R. Ball ex E. G. Voss. Ohio J. Sci. 50: 187. 1950.
Sparganium chlorocarpum Rydb. f. *acaule* (Macoun) E. G. Voss. Rhodora 68: 436. 1966.

EPONYMY OF ED VOSS

Asteraceae *Solidago vossii* J. S. Pringle & Laureto. Michigan Bot. 49(4): 108. 2010 [Oct. 2010]
Orchidaceae ×*Blepharopsis vossii* (Case) Efimov. Novosti Sist. Vyssh. Rast. 40: 48. 2009 [2008 publ. 30 Mar. 2009]
Orchidaceae *Platanthera* ×*vossii* Case. Michigan Bot. 22: 141. 1983
Orchidaceae ×*Platanthopsis vossii* (Case) P. M. Br. N. Amer. Native Orchid J. 8: 37. 2002 [30 Dec. 2002]

GRADUATE STUDENTS SUPERVISED BY ED VOSS

Ph.D. 1962. Alfred E. Schuyler, Curator Emeritus, Philadelphia Academy of Sciences
Ph.D. 1965. Ronald L. Stuckey, Professor Emeritus, Ohio State University
Ph.D. 1971. Richard W. Scott, Curator, Central Wyoming College Herbarium, Riverton. (Co-chair with W. S. Benninghoff)
Ph.D. 1976. Thomas Duncan, Professor Emeritus, University of California, Berkeley (Co-chair with W. H. Wagner, Jr.)
M.Sc. 1983. Margaret Bliss, Private Sector
Ph.D. 1983. Kerry S. Walter, BG-BASE (UK) LTD. Royal Botanic Garden Edinburgh, Scotland, UK (Co-chair with W. H. Wagner, Jr.)
Ph.D. 1983. Tom Rosatti, Scientific Editor, Jepson Herbarium, University of California, Berkeley (Co-chair with W. H. Wagner, Jr.)
Ph.D. 1988. Brian Hazlett, Professor of Biology, Briar Cliff University
Ph.D. 1992. Rob Naczi, Arthur J. Cronquist Curator of North American Botany, The New York Botanical Garden (Co-chair with A. A. Reznicek).

"FRATERNALLY, ED"—A REMEMBRANCE OF ED VOSS FROM UNDERGRADUATE DAYS

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I met Ed Voss (Fig. 3) in 1947 (65 years ago!), when we were both freshmen at Denison University in Granville, Ohio. Ed had enrolled in September 1946. I was discharged from the Army in November and enrolled at Denison in January 1947. By the end of the spring semester, we were members of the same fraternity. Over the years since then, he always closed his letters with the words, "Fraternally, Ed."

Those who know us might not think of either Ed or me as a typical fraternity man, and that would be correct. An understanding of how we came to be frater-

FIGURE 3. Ed Voss as an undergraduate at Denison University.

nity brothers requires an understanding of the times and the environment. Academically, Denison afforded its students a first-class education and a close working relationship with the inspiring professors. Socially, college life at Denison in the 1940s was in some ways like that depicted in early Hollywood movies, complete with everything from sweetheart serenades to pep rally bonfires. Among other traditions, coats and ties were required for dinner, and following the meal we remained at the table and sang college and fraternity songs. Of the male students, 95% joined a fraternity, and the other 5% were mostly students living at home. For the men residing on campus, belonging to a social fraternity was almost a necessity.

Fortunately for those of us inclined toward independence, there was the American Commons Club (ACC). Despite the lack of Greek letters in the name, ACC was a genuine fraternity. We had a residential house on campus with study rooms, a sleeping porch, a dining room, and a large lounge for social events and meetings of the brotherhood. Much of our college education came from life in the ACC house, and it influenced us for the remainder of our years. For Ed Voss, belonging to the American Commons Club was a special source of pride because his father had been a member a generation earlier.

After graduating in 1950, I continued to do occasional ACC work for the next few years, as did other members. Ed continued on for the next 60 years. His work for the group ended in May 2009, with the final edition of "Commoner News," an alumni newsletter he edited. The American Commons Club at Denison had closed down some years earlier.

Ed and I both became botanists. We made our way to botany separately, by a kind of convergent evolution. Our friendships started at Denison. So also did our affection for the university and fraternity.

During our senior year, Ed served as secretary for the fraternity. The highlight of Monday evening business meetings was Ed's reading of the minutes of the previous meeting, written and read with his customary logic and wit. He also wrote and edited that year a weekly in-house newsletter for ACC members: GRANVILLE GRAVEL, "We leave no stone unturned."

BEYOND THE BOTANY—LIFE WITH ED VOSS

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I was honored to share a home with Ed Voss for three years, to assist him in several courses at the Biological Station, and to be on his short list for camping companions at the end of many summers. He was on my doctoral committee, and was an advisor, advocate, and friend for many years.

Ed was the ultimate curator. His house was curated. His car was curated. His medicine cabinet was curated, and his refrigerator was curated. At supper following a night when I had left a half-empty bottle of wine in the refrigerator, I was presented with the statement: "I trust that bottle of alcoholic beverage on the milk products shelf is NOT for our mutual consumption?" Hard to answer that correctly! His basement had a complete set of National Geographic from day one, but no TV. Surprisingly, his yard held several alien species. I planted an *Abies concolor* in the front yard by the drive only after a prolonged discussion about what image that would convey.

I am sure that Ed was comfortable with me as a Teaching Assistant, not because of my botanical ability, but because I could keep the boats running, tie them on the trailer securely, and keep the cars running. I was happy with that role, as my guesses at plant ID were usually wrong anyway. I learned to say "Here's an interesting find," instead of "This looks like a gentian." If it wasn't a gentian, even though it looked like one, I was in minor trouble. I increased my value when I, somewhat guiltily, confessed to him that I had agreed to assist Howard Crum in Bryophytes & Lichens. Ed snorted, and said "Good. Now I won't have to stoop to identify the little stinkers."

The most relaxed and fun aspect of life with Ed was during the end-of-summer camping trips. Sometimes there would just be the two of us, and sometimes three. We always sought out Lake Superior shorelines, for there we found the greatest privacy and the best botany (Fig. 4). Each trip had a theme. We might focus on exploring new areas, or on following a newly acquired map. One year it was a search for a new record for *Empetrum*. Some themes recurred, such as finding and consuming vast quantities of blueberries. Six species were available on the shore in August, and here, mixing of species was permissible! Pies, puddings, or fresh—any way was fine. Ed's appreciation of wild things edible extended to the fungi. I honestly believe that he was saddened when fungi were degraded and removed from the plant kingdom. That did not, however, affect their edibility. Chanterelles were particularly relished. One summer I discovered a Sulfur Shelf that fed us for several days—omelets, scrambled eggs, chili, and mixed with vegetables. We never had the nerve to try boletes or amanitas, and successfully lived on. We reminisced over Alex Smith's contention that ALL fungi were edible. Some, however, would kill you.

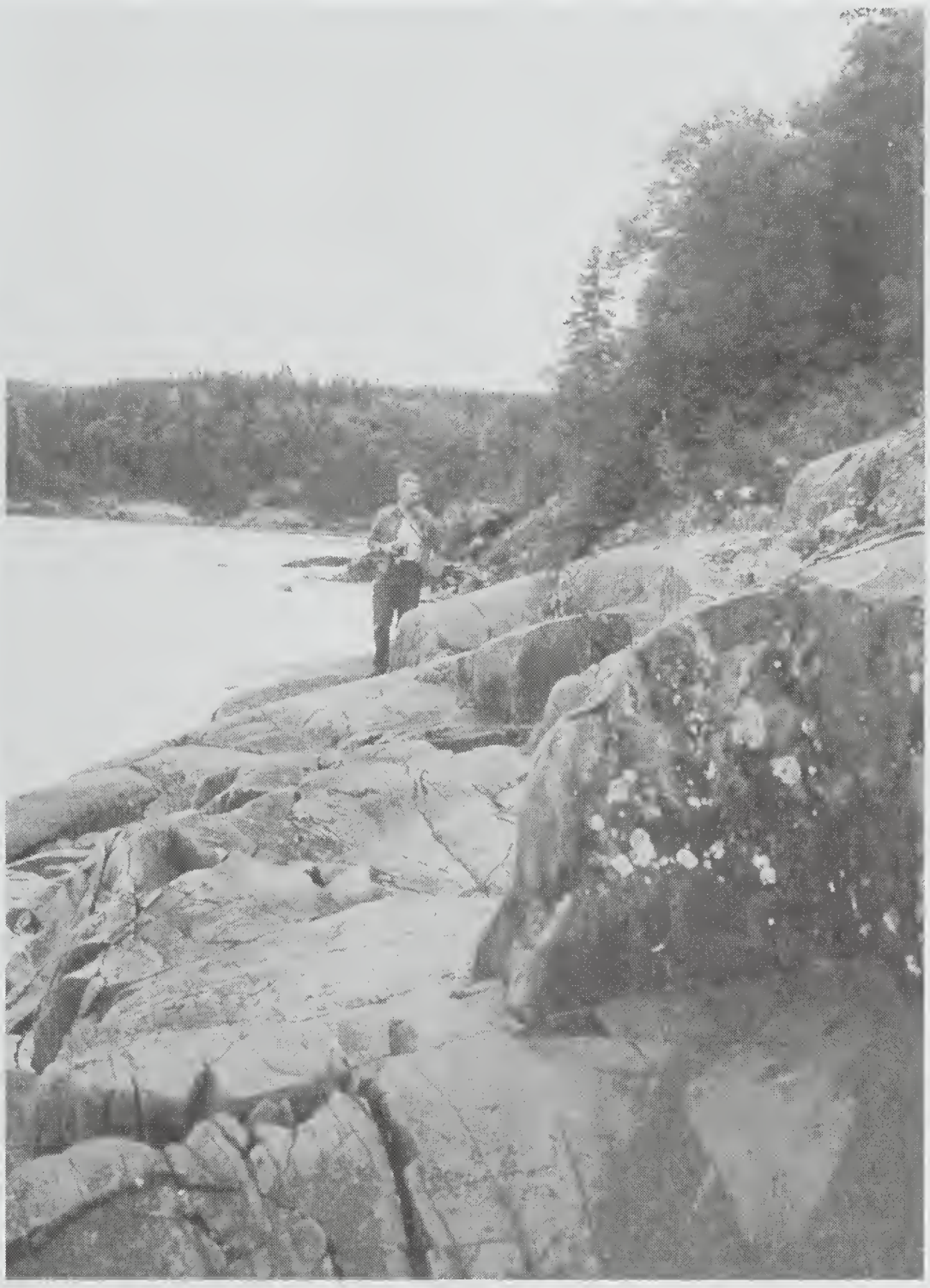

FIGURE 4. Ed Voss with vasculum looking at Pictographs on Lake Superior. Photo by John Russell.

A trip would begin with packing the car in a precisely calculated manner, so the load would not shift, and so that the driver could just barely see out the back window. Ed never got into the backpacking equipment thing, even though this would have solved lots of problems. The nine by nine foot umbrella tent, tediously coated with waterproofing, and its box (saved since purchase) of aluminum poles, went in on the bottom. It was not pushed forward, as it had to come out first so it could be erected and serve as a depot into which to unload the rest of the gear. The two-burner Coleman stove in its original box, the Coleman lantern, also in its box, the condiments, food, and utensils went in, and the toiletries went on top, always at the ready. Once I returned the toilet tissue to the condiment box. Ed's subtle response was to hide it from me, as I had from him. The cooler with frozen canned ice in ancient rusting tins went in on the left. A custom-cut shelf of plywood was laid between the window ledges behind the

FIGURE 5. Ed Voss reading at 3 mile creek. Photo by John Russell.

rear seat to support small items, a plant press, small toolbox, and county maps. Backpack gear would have solved space problems, but it never entered the picture. One year, catastrophe nearly struck when Jeep changed models. Renault influence caused the scrapping of the old large Cherokee design, with its lift gate and tailgate, replacing it with a unit body design. The old light blue Cherokee was badly rusted, tailgate nearly gone, and windows sticky. Ed got a new dark blue Cherokee. It was calculated to be 31% smaller in load area, if you measured all the way to the roof. I pointed out that the area above the shelf had to be left free anyway, and the calculation was revised to under 20%. I designed and cut a second piece of plywood to serve as a tailgate upon which to eat and press plants (the new Cherokee had only a single liftgate). The old shelf was cut down to accommodate the narrower width. Now the only problem was to reduce the load by about 15%. Packing tighter seemed the answer, not going to backpack gear! It was done, and the trip was accomplished, with the only problem being the front floor of the new Jeep being recessed so that it wasn't possible to just sweep Lake Superior sand out the door. Why would anyone design a four-wheel drive vehicle that way? Because they were French.

Eggs for breakfast—don't cook the bottoms hard. Bring your own coffee or tea, for Ed didn't do stimulants. How did he ever get his degree? Oatmeal with bilberries was better! We'd pack sandwiches for lunch and set out on a daily hike, following maps from the DNR and always seeking blueberries and mushrooms. A three-course dinner highlighted our evenings. Often we had brought fresh corn from Clem Burr's farm east of UMBS. We ate the perishables first, as

FIGURE 6. Ed Voss having a lunch break amidst lichens. Photo by John Russell.

the canned ice could be expected to last 2.5 days if the cooler was placed appropriately in the shade and the arc of the sun in the sky was properly calculated. Evening was for bathing, and then reading (Fig. 5). Reading was continued in the tent, warmed by the Coleman, until an hour or so after dark when it was time to retire. This was also the time devoted to going over field notes, although camping trips were probably the times that Ed did the least hardcore botany. They were his "vacation" time, a time when perhaps he was most relaxed (Fig. 6) and under little pressure to perform his botanical duties. (I realize that a "relaxed Ed" is somewhat oxymoronic.)

Often sadly, there was little room in the Jeep for souvenirs from the shore. I wanted to bring a pail of beach sand back for my classes, but had to package it in small containers that could be fitted into small interstices in the load. I rationalized that we could bring back a volume equal to that of the food we had eaten. A poor substitute for food, Ed opined. One thing I was able to smuggle back was a very strangely shaped burl on a jack pine trunk, which, when skinned of its bark, resembled the lower half of a human. When it was unloaded back in Mackinaw, Ed professed surprise, but I think he knew it was contraband all along. We did haul agates, the occasional pressed plant, and insects back to town. The Mackinac Bridge seemed the gate back to reality.

I suspect that Ed enjoyed these weeks on the Superior shore more than any other times of his busy life, and I take solace in the belief that he is spiritually there today, in a place where essence is more important than the physical.

ED VOSS—FIELD BOTANIST IN SUMMER, CURATOR IN WINTER

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No, I'm not suggesting that Ed led a dual botanical life. He was devoted to the vascular (especially the flowering) plants of Michigan at all seasons and throughout his life. But his botanical seasons were definitely compartmentalized, like so many other elements of his life.

In summers (from mid-May to the Labor Day weekend, slightly longer after retirement) Ed was based "up north," staying at the Biological Station on Douglas Lake while teaching (for 36 summers; 1963–1974, 1976–1998, 2003; plus four years as a teaching assistant, 1949, 1951–1953) (Fig. 7). Ed attended the International Botanical Congress in Leningrad in 1975, John Thieret substituting for him that summer. When not at the station, Ed stayed at his cottage on the straits near the tip of the Lower Peninsula looking out over the Mackinac Bridge.

He likely went in the field more often than any other botanist in the region. I always wished I could have as much field time as Ed. His field work, though, was usually tightly focused and organized, like everything else in his life. When he was teaching, he was scouting class trips and looking for new areas to take people or show them special things, such as transient species of disturbed habitats, which were always a challenge. However, he was always keen to explore a new bog or fen, and was especially interested in comprehensively documenting the plants of favorite areas in the straits region, including Grass Bay, the Headlands, or Saint Helena Island (Voss 2001).

He built a great body of knowledge about plants of the Biological Station area, and his work, added to earlier collectors, made the Douglas Lake region (Emmet and Cheboygan counties) one of the best known in the state. In fact, this flora, including all the interesting Great Lakes endemics centered on the straits region, was the subject of his doctoral thesis (Voss 1954) and most of his botanical publications prior to 1957. The Douglas Lake region was so well known that it was a banner day when a new native species was added. So I was particularly lucky on 9 August 1978, the very first time I went out with Ed in the region, to spot right in the trail to Mud Lake Bog, *Torreyochloa* (*Puccinellia*) *fernaldii*—a new, though inconspicuous, native grass to the Douglas Lake area (which ended up as Voss No. 15,000). I felt then that I had passed muster as a field companion.

Ed also collected in southern Michigan in the fall, often in conjunction with scouting for the well-known aquatic plants course which he taught for many years in Ann Arbor. He was especially fond of the Lake Erie marshes, and was interested in their dynamic changes with fluctuating lake levels. Whenever I was with him, he always enjoyed seeing if this was a year that the very local *Bolto-*

FIGURE 7. Ed Voss (second row, far right) with the 1963 UMBS Aquatic Flowering Plants class. Photo UMBS archives.

nia asteroides or *Sagittaria montevidensis* would be in evidence. He was also interested in Great Lakes shoreline dynamics "up north," with his Cecil Bay transects, conducted over many years, and there is little doubt that the habitats of the Great Lakes shorelines were a special interest to Ed his entire life.

Another important element for Ed was, of course, trying to make the maps in the Michigan Flora (Voss 1972, 1985, 1996) represent the distributions of species accurately. As time allowed in the summers, he ranged widely over the state. He once noted that he had collected plants in every county in the State (and on many of the islands). His collection numbers reached nearly to 17000, the vast majority from Michigan, far exceeding the totals of any other Michigan collector. These collections will be one of Ed's lasting legacies. Ed also made important collections from the Ontario shore of Lake Superior, and occasionally collected farther afield—usually in conjunction with International Botanical Congress field trips. His greatest activity was in the early years of the Michigan Flora project; in 1957, he collected 2088 numbers, on some days gathering nearly 100 numbers from interesting sites. He made collections until 2008. Much to some field companions dismay, Ed moved quickly through areas—but he missed little. Ed's collecting was very even handed. He liked sedges and never avoided them, freely collected willows, and was particularly fond of aquatics, though he did claim not to like ferns (despite collecting them assiduously). He was fearless about getting wet feet (or more) and was very willing to wade in to get a special wetland plant (Fig. 8); biting insects and other discomforts did not seem to bother him when he was on a mission. When he was doing serious collecting, he always had his pick slung in a loop and clippers in their sheath on his jeans—high botanical fashion—so was not afraid to tackle tough-rooted weeds either.

His vehicles, for a long time Jeeps, then Ford Explorers, were selected with the purpose of serving as a field vehicle. The ideal vehicle had a back tailgate that lay down to produce a surface useful for pressing and other related duties. When tailgates were converted to a lift up action it caused Ed consternation, though he did realize it provided some rain shelter. He wanted a vehicle where the floor did not have a raised lip at the doors, so that debris and sand could be easily swept out, and he decried the loss of the front bench seat, which made for

FIGURE 8. Ed Voss sinking in Barclay Lake in 1997. Photo by John Russell.

convenient placement of a box with collecting accoutrements. In fact, his next-to-last vehicle was a special order to get that bench seat.

Ed was a careful collector, as one might expect from a student of Rogers McVaugh, and his specimens were always of high quality; carefully prepared, complete, with good notes, and consistent, accurate labels. His scholarship was based on specimens and he knew firsthand how difficult it was for a researcher to deal with poor specimens. He carried a vasculum in the field where feasible, and often carefully floated out aquatics to make the best collection possible. His press was always handy in the vehicle (see Fig. 12). He recorded data as soon as possible in the field and anybody who collected with him knew his pocket-sized aluminum clipboard (see Fig. 20) with rubber bands disciplining the sheets within. These roughly written, barely legible notes were neatly transferred into a small three-ring binder (Ed freely admitted that his handwriting was not the best), which served as his permanent field notes and were augmented with final determinations, notations about herbaria to which duplicates were distributed, and revisions by specialists. These will be deposited at MICH.

Besides collecting specimens, Ed always wanted to know and recognize Michigan species as living plants in their habitats (Fig. 9). This was very important to him for many reasons. He described habitats in the Michigan Flora volumes from data compiled from herbarium specimens, but he always liked to note specific information from his own experience, as information derived from specimens was often generalized and imprecise. He liked to include helpful field

FIGURE 9. Ed Voss admiring *Lithospermum caroliniense* during the 2004 minicourse. Photo by John Russell.

FIGURE 10. Ed Voss photographing at Crisp Point. Photo by John Russell.

recognition hints from his own experience. He also liked to test his keys as he wrote the treatments. All this, of course, was essential for writing the original keys that made his floras so accessible. He disdained floras that were uncritical compilations from literature and specimens, and had choice words to say about people who wrote about plants as if they knew them, but from their comments, had obviously never seen them alive.

Ed deeply enjoyed being in the field, especially in bogs, fens, and on his beloved Great Lake shores, dunes, and beaches (Fig. 10). It was far more than a career, it was his, singular, life. A highlight every year was his annual week camped on Lake Superior just before coming back to Ann Arbor, usually shared with a botanically minded friend. This was the closest he ever came to taking a vacation (see article by John Russell).

Ed's life as a Curator, during the academic year was, of course, a natural extension of his work as a field botanist collecting plants. But for Ed, curation was also a critically important element of his research on the flora of Michigan. They were inseparable, as specimens were his basic research tools, serving not only as documentation for the occurrence of plants in Michigan, but also as the raw material for the development of his original keys, and his synthesis of habitats, flowering times, etc., across the State, especially for plants with which he had little or no familiarity in the field. Ed was very concerned about specimen quality even after collecting, and carefully watched the mounting of specimens, and the herbarium staff heard about it if plants were mounted in such a way as to impede study of diagnostic features.

Perhaps the most time consuming element of Ed's curation was the enormous

effort that he put into supplying accurate identifications for the 230,000 or so specimens utilized for the Michigan Flora project. Ed was very strict about records for the Michigan Flora; *every dot* on *every map* in his volumes was based on specimens that he personally studied and determined. If he had not seen a specimen, the record didn't exist. Having to some degree assumed that mantle, I know how much time it takes to do the painstaking determinations of plants that Ed did for about 60 years, not only for specimens at the University of Michigan Herbarium, but also numerous collectors and students all over the State and even the Great Lakes region. It meant consistent late nights and weekends working at the Herbarium. But his helping and encouraging others in this way was probably as helpful to Great Lakes Botany over the years as his teaching and his flora.

Specimens labeled with obscure localities were a particular challenge to Ed, and he worked assiduously to locate them at least to county. Very often, these collections with obscure data were historical specimens of considerable potential value for information about past distributions, and he would sometimes spend many hours researching collectors habits, itineraries, and other details to produce a more complete label or to resolve apparent contradictions. This was especially important for Michigan because immediately upon achieving statehood in 1837, the Michigan Legislature authorized a geological survey of Michigan's natural resources, headed by Douglass Houghton. One of the important duties of this first survey was to collect plants to document the flora, and thus Michigan has an unusually good series of collections before extensive settlement—but with many hard to-place localities. This work led to a helpful catalog titled *Gazetteer of Some Possibly Puzzling Collecting Localities for Michigan Plants* (Voss 2005; and also at: *http://www.lsa.umich.edu/herb/michvoss/index.html*) that summarized his notes about localities gained over a half century. Naturally, Ed's own labels were models of consistency and precision. I recently learned that early contact with Lloyd Shinners in 1951 at the Biological Station may have provided Ed with the format for his specimen labels. He would rail against vague and meaningless statements on labels, pointing out that locality descriptions like "south of Ann Arbor" could mean Ohio, or worse (Voss 2002).

In the course of all this study, Ed became an expert on the handwriting, label styles, and collecting and labeling habits of all of the major Michigan and Great Lakes collectors, ranging from the highly productive and talented, but disorganized and eccentric, Oliver A. Farwell (whose initials Ed thought quite appropriate), to collectors he admired for their diligence and perspicacity in finding rare plants and new records. He noted Charles K. Dodge's obsession with having his address on every label, sometimes even two or three times, regardless of where the plant was collected, or certain collectors inability to correctly read maps. With his focus on collections, and the tangible results—send in a collection and a dot goes on a map—Ed stimulated many people to collect plants in their local region to contribute to the Michigan Flora project. And, of course, contributors always got back typewritten lists of corrections to their determinations.

With Ed's attention to label accuracy and strong interest in historical collections, it is no surprise that he also had a strong interest in Botanical history. A curator working with historical specimens has to be part historian, part geographer, part handwriting expert, and part detective. Ed was all of those in good measure.

His historical detective work culminated in his very readable 1978 book on botanical exploration of the western Great Lakes region: *Botanical Beachcombers and Explorers: Pioneers of the 19th Century in the Upper Great Lakes* (Voss 1978). This is a work notable for its accuracy, deep detail, and also for having 343 sometimes lengthy footnotes crammed into its 100 pages! Ed delighted in having unearthed, from some specimen label or obscure reference, a tidbit of information that shed new light on some collector and their method of operation. All these he considered important items for a curator.

Ed recorded all label data, with exasperating literalness, for the collections he examined for the Michigan Flora project for many years on record slips (*not* index cards, as Ed would quickly correct anyone who referred to them as such) and, starting in 1991, into a computer database. Though never really warming to computers and databases, Ed realized their value for his research immediately, and the Michigan Flora database quickly grew to be the largest one at the Herbarium, as Ed not only supervised entering all new collections he examined, but also the conversion of his paper record slips into digital form. Ed developed precise and detailed instructions—running to six single spaced pages—for entering records into the database, and of course, he requested that a special proofing routine be built so that he could carefully proof *each individual record* by comparing the specimen label or the record slip to the database entry. Not being one to change a well-developed routine, the printed output from the database had to precisely match the format of the record slips—as Rich Rabeler and I discovered when we created that database.

Ed decried carelessness, noting how commonly people misrepresented collection localities in the literature—mistaking the collectors address (often printed on labels from the late 1800's and early 1900's), as the place the plant was collected or coming to the wrong conclusion about which of the numerous "Mud Lakes" a plant was from. Michigan specimens without County, or where the locality was unclear (or obviously incorrect) were always annotated with the correct data if Ed could discover them. It is a tribute to Ed that the distributions of Michigan plants are so well presented in his flora, despite error-prone collectors like Farwell devoting their careers to the State. As of April, 2012, the task of entering all the Michigan records into a database is now complete, finishing a task Ed started at the inception of the Michigan Flora Project in 1956 (Fig. 11).

Ed's approach writing his Michigan Flora work was very much an extension of his curation, and was as methodical and deeply detailed. His command of botanical literature was phenomenal, as reflected in his years of contributing *Michigan Plants in Print* to *The Michigan Botanist*. He was a bibliophile, and had an extensive (and, not surprisingly, well curated) personal reprint and book collection centered on Michigan plants. He was very interested in the biology and ecology of Michigan plants, and often had concise but perceptive comments on those topics in the Michigan Flora. He also evaluated all literature that he used for the flora with his deep and broad knowledge of plant nomenclature, derived from his years of service to the nomenclature committees of the International Association of Plant Taxonomy, as well as with his knowledge of plants in the field and the herbarium. Not surprisingly, the literature often was judged sadly lacking. However, Ed did not himself delve into researching unresolved

systematic questions in the flora, though he encouraged others to do so, and was usually aware of the problems. Ed very much viewed his flora as a synthesis of knowledge available to date. As a consequence, Ed made fewer nomenclatural innovations for the flora than one might have expected, described no new species, and only two new entities; rare color forms of two interesting *Cirsium* species, the Great Lakes endemic *Cirsium pitcheri*, forma *magenteum* (Fig. 13), and the prairie and jack pine barren *Cirsium hillii* forma *albiflorum*. This allowed others to name plants in honor of Ed, including the very rare hybrid *Platanthera* ×*vossii*, and the Michigan endemic *Solidago vossii*.

FIGURE 11 (left). Ed Voss studying herbarium specimens at the inception of the Michigan Flora project. Photo: Asa Gray Bull. n.s. 3: 277–279. 1957.

FIGURE 12 (bottom left). Ed Voss pressing plants. Photo by Bob Vande Kopple July 2007.

FIGURE 13 (bottom right). Holotype of *Cirsium pitcheri* forma *magenteum* collected by Ed. Photo by H. Huggins.

THE BOTANICAL TEACHING LEGACY OF EDWARD G. VOSS AT THE UNIVERSITY OF MICHIGAN BIOLOGICAL STATION

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The end of May marked Ed Voss' annual trip to northern Michigan—his botanical getaway since well before he became Professor of Biology and Curator at the University of Michigan, Ann Arbor. This locale fortuitously provided his inspiration for decades of pioneering research on the Michigan flora. His grandfather had acquired their cabin on the Straits of Mackinac in 1930 to avoid hay fever in their hometown of Dayton, Ohio. In September of that year, at the age of one, Ed spent his first night along the Straits (Voss 2008). It was here in northern Michigan that Ed established a lasting legacy from the many lives he touched in the classroom, and field, at the University of Michigan Biological Station (UMBS).

Ed became a faculty member at UMBS in 1963 and taught four courses during his tenure: Systematic Botany (1967–1969, 1971–1974), Boreal Flora (1967–1974, 1976–1994) (Fig. 14), Aquatic Flowering Plants (1963–1969; 1971; 1991), and Field Botany of Northern Michigan (1995–1998; 2003). From 1963–2003, he would miss only five summer sessions at UMBS. Ed treasured his time at UMBS. As he once noted, "UMBS is a place you cannot stay away from!"

Ed taught his students with an enthusiasm that was legendary. It was peppered with exclamations and tempered with precision to help students understand the challenges, nuances, joys, and importance of botany. For example, on a class field trip in 1995, Ed remarked with irritation about a motel named "The Birches" that was surrounded by aspen. He curtly observed to the class that, "There is a lot of botanical ignorance out there!" It was this dedication to the appreciation of the natural world, and of its accurate depiction, that were cornerstones of his teaching. The many students he inspired have become land managers, park rangers, policy makers, doctors, lawyers, professors, and of course, well informed citizens of the botanical world (Fig. 14).

As we reflect on our experiences of Ed in the classroom and the field we are struck by some of the traits that made Ed such a singular and inspiring botanical educator.

FIGURE 14. Ed Voss in 1974 with his Boreal Flora class. Photo UMBS archives.

Ed was undaunted by field conditions. Lightning, heat, rain, wind, and least of all, mosquitoes, were no match for Ed. His sole focus was discovering and teaching plants, with total disregard to environmental conditions that surrounded him or his students. For example, when teaching the beautiful and diminutive orchid *Malaxis unifolia* Michx. at Ryerse Lake in the Upper Peninsula (on years when it could be found!), students would giggle as Ed was undeterred, and utterly enraptured, despite the mosquito sucking blood from his eyelid. Each new discovery was a treasure for him, despite having seen these old friends many, many times over the decades. His enthusiasm never dulled, and it was this infectious excitement that motivated us all (Fig. 15).

The only thing with the power to sway Ed from his botanical bliss was his stomach. Despite his svelte physique, Ed was a voracious predator. Lunch or dinner was never skipped. And he was notorious for taking heaping first and second helpings at the dinner line, and rarely made conversation while at his favorite table. We suspect he felt that such discussions would get in the way of satisfying his enormous appetite.

Ed loved sharing the beauty of the Great Lakes region. Ed took great pride in the beautiful places that he scheduled for the course. They included Grass Bay (Cheboygan County) where students could traverse the upland mesic forest down to the interdunal swales along the shore of Lake Huron; the mouth of the Two Hearted River where students could stand atop a massive sand dune and look to one side and see the vast open water of Lake Superior and the tannin rich color of the river on the other; the old growth beech-maple-hemlock forests of the Headlands near Mackinaw City; and of course the unforgettable bogs and

FIGURE 15. Ed Voss gleefully holding up Poison hemlock (*Conium maculatum*) while teaching. Photo by C. Mom.

fens of the Upper Peninsula (Fig. 16). Each of these habitats held a treasure trove of plants that were unique to that site, and it was the combination of these plants that elucidated the ecological context of these unforgettable landscapes.

When it came to spectacular locations, Boreal Flora students were fortunate to experience a truly remarkable botanical excursion: the Canadian shore of Lake Superior. For many "BoFlo" students, the Canada trip was the highlight of the summer. Driving a procession of tightly packed vans, the class ventured across the border synchronized to Ed's precise itinerary. Although the logistics of the trip could cause Ed anxiety, there was no doubt that this was the highlight of his year. Ed's love of northern floras, plant geography, geology, and history were epitomized along to the panoramic backdrop of Lake Superior.

In addition to these many beautiful places, Ed also enjoyed waste ground sites, or 'stump dumps' as he affectionately called them. These sites were not easy to appreciate in part because, as Ed noted, waste grounds could be "as hot as a pancake griddle", but there was great wisdom in these choices. To Ed, these sites served two purposes. First, they provided abundant material for teaching a great variety of floral and vegetative forms, which was ideal for introductory students of plant diversity. Second, they helped to recreate the kind of destruction and openness that resembled the post-glacial landscapes, so prominent in the origination of Michigan's flora. He was apt to remind students that the ~2,800 species of Michigan's land plants had arrived there only within the last ~12,000

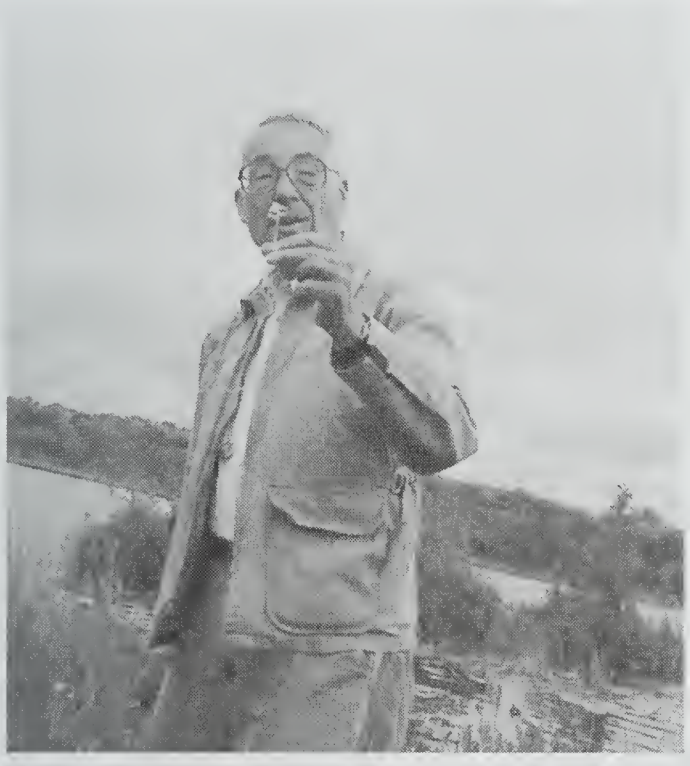

FIGURE 16. Ed Voss teaching on the bog mat at Ryerse Lake in the Upper Peninsula. Photo by C. Davis.

years. It was in this context that he delivered lectures about how invasives, both natives and non-natives, often found their way onto new landscapes. It was an incredibly effective, and brilliant teaching tool. Not to mention that many of his favorite plants–natives especially–could only be found in these environs (Fig. 17). The choice species of the waste ground of the Mackinaw City vicinity included Strawberry Blite (*Chenopodium capitatum* (L.) Ambrosi), *Leucophysalis grandiflora* (Hooker) Rydb., Pink Corydalis (*Corydalis sempervirens* (L.) Pers., now known as *Capnoides sempervirens* (L.) Borkh.), and Golden Corydalis (*Corydalis aurea* Willd.). He would spend hours scouting for these species long after he retired from teaching. Each summer Ed would revel in rediscovering these unpredictable species in his favorite vacant lots and gravel pits.

Ed was meticulously organized. Taxonomists like Ed are often guilty of being overly tidy, and Ed was no different. For every class he was prepared with a well-worn manila envelope containing relevant maps and other documents, hand lens on sturdy upholster's cord (Fig. 18), rock pick in a belt loop of his trousers, and appropriate footwear (e.g., soccer cleats for wetlands) (Fig. 19). Many will remember his carefully curated plant, insect, and book collections, but a hallmark of Ed's organization was exemplified by his field notes placed neatly inside a small aluminum sided jacket. These notes were always typed on the clean side of scrap paper that were cut to fit his notebook precisely (Fig. 20).

These cards served several purposes including expected, but yet undiscovered, county records for Michigan. Whenever there was an obvious gap in these records, Ed was quite pleased to find the undocumented species in question no matter how common or nondescript. These notes helped to produce glorious maps of species' range distributions of Michigan, which were the basis of his classroom discussions of plant biogeography and the maps in the *Michigan Flora* volumes (Voss 1972, 1985, 1996).

Ed was quite fond of the numerous distantly related species whose distributions were found primarily in western North America, but were (strangely) also

FIGURE 17. Ed Voss at a waste ground site on the Darrow property near Mackinaw City teaching Golden Corydalis, *Corydalis aurea*. Photo by C. E. Hellquist.

FIGURE 18. Ed Voss in 1984 examining a specimen with his hand lens. Photo: UMBS archives

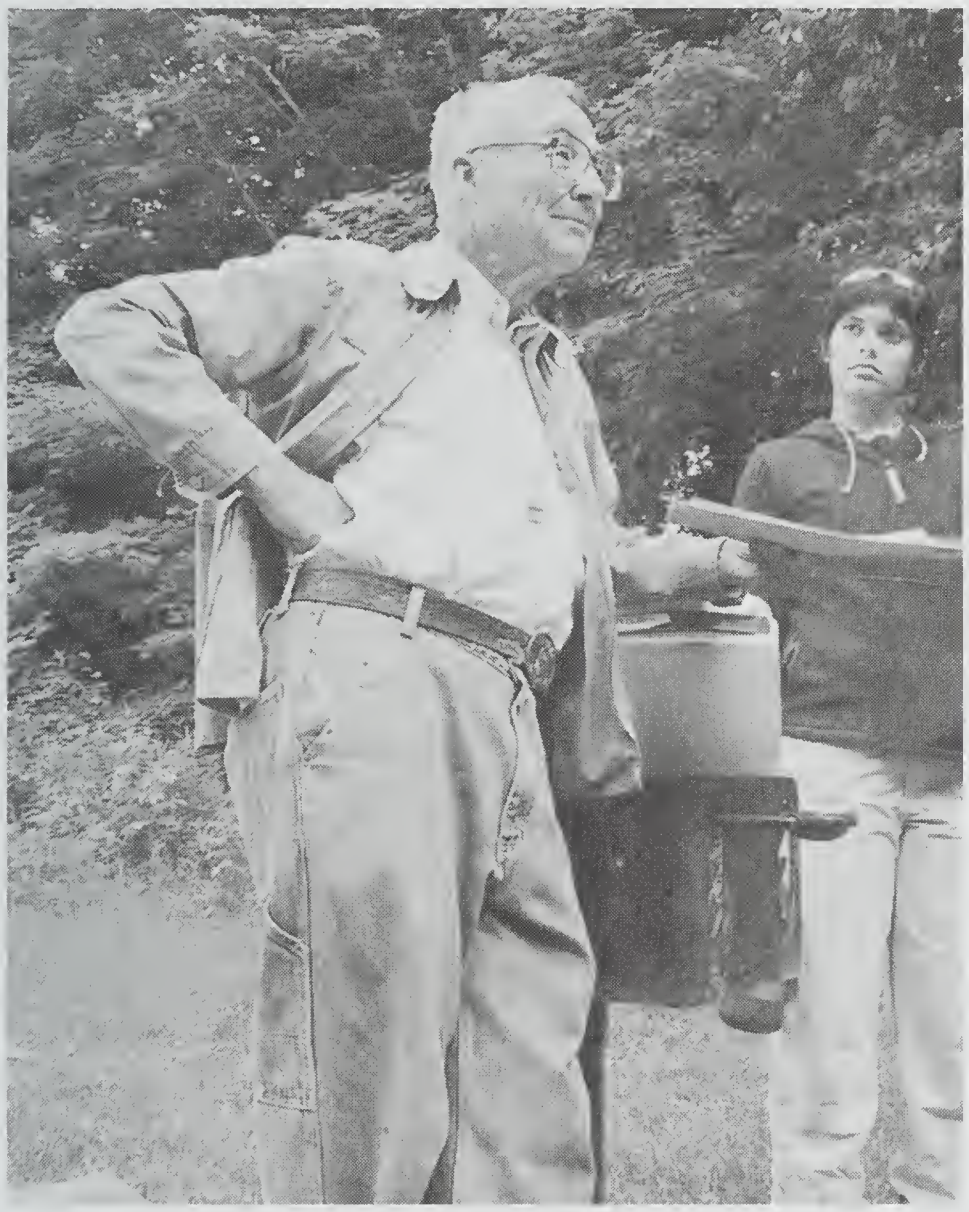

FIGURE 19. EGV teaching one of his last lectures in 2003 near Pictured Rocks National Lakeshore. Photo by C. Davis.

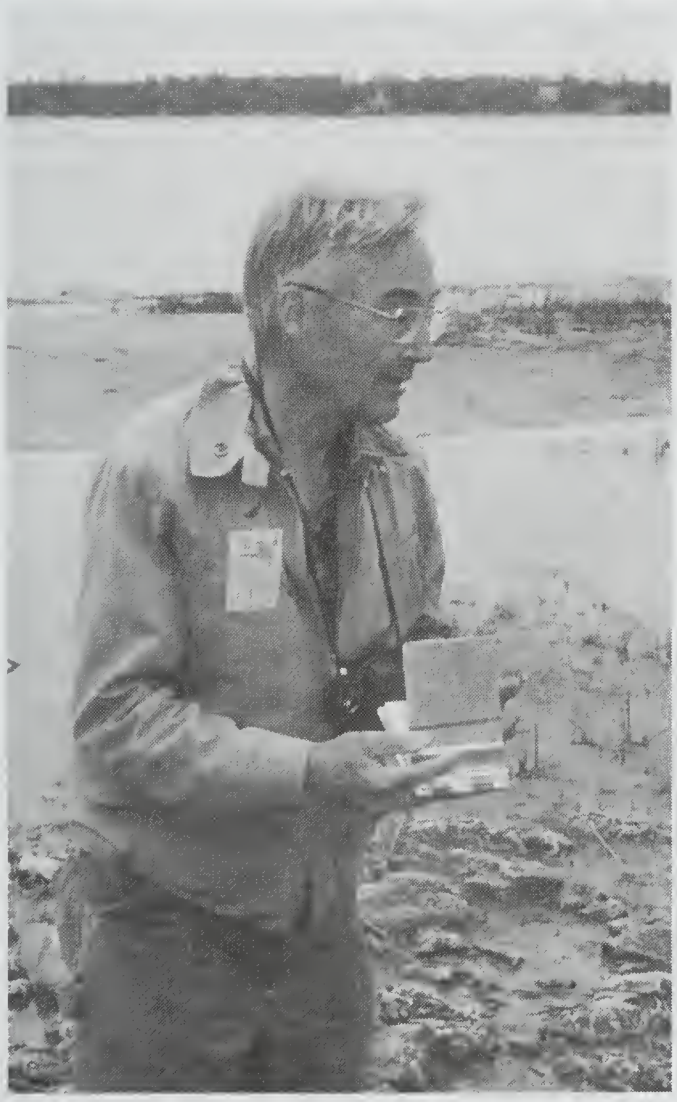

FIGURE 20. EGV with his aluminum sided notepad on the Bruce Peninsula, Ontario, Canada. Photo by C. Davis.

represented far from their center of diversity to include the Great Lakes region. It was a fascinating topic on which he produced an excellent summary (Marquis and Voss 1981), co-authored with one of his former students, Robert Marquis, now a Professor of Ecology at the University of Missouri, St. Louis.

One of the most curious western disjuncts is *Pterospora andromedea* Nutt., an unusual mycoheterotroph found occasionally along the shores of the Great Lakes. It was on a scouting trip for this plant near Pte. aux Chenes in the Upper Peninsula that another important use of Ed's note cards became apparent—direction finding. Ed typed the directions (to the tenth of a mile) to find *Pterospora*. These directions included the obvious, but also the number of telephone poles to pass along the way, as well as the local botanical landmarks to find the spot. It was truly remarkable, and led perfectly to the site that had not been visited for at least a decade. Today, botany students visit many of the same sites (and plants) that Ed vigilantly recorded in his notes season after season.

Ed was the "Program Director" of "Plant TV." Although Ed was not the originator of "Plant TV", which traced back to a student of Professor Elzada Clover in 1966 (Voss 2008), he became synonymous with its development and use as a study aid. While in the field with students, Ed or his teaching assistant (TA) would carefully collect a representative of each plant for display in glass cases behind LaRue Library and later Gates Lecture Hall. Occasionally, he would circulate the plant for closer inspection before carefully resting it in the vasculum ("Into captivity!", as he would gleefully exclaim). On one occasion, while passing around the delicate Enchanter's nightshade (*Circaea alpina* L.), he warned the students, "Don't squeeze the pipes!" Suffice to say, Ed was very pro-

FIGURE 21. Plant specimens being prepared for "Plant TV". Note Poison-ivy in beer bottle. UMBS archives.

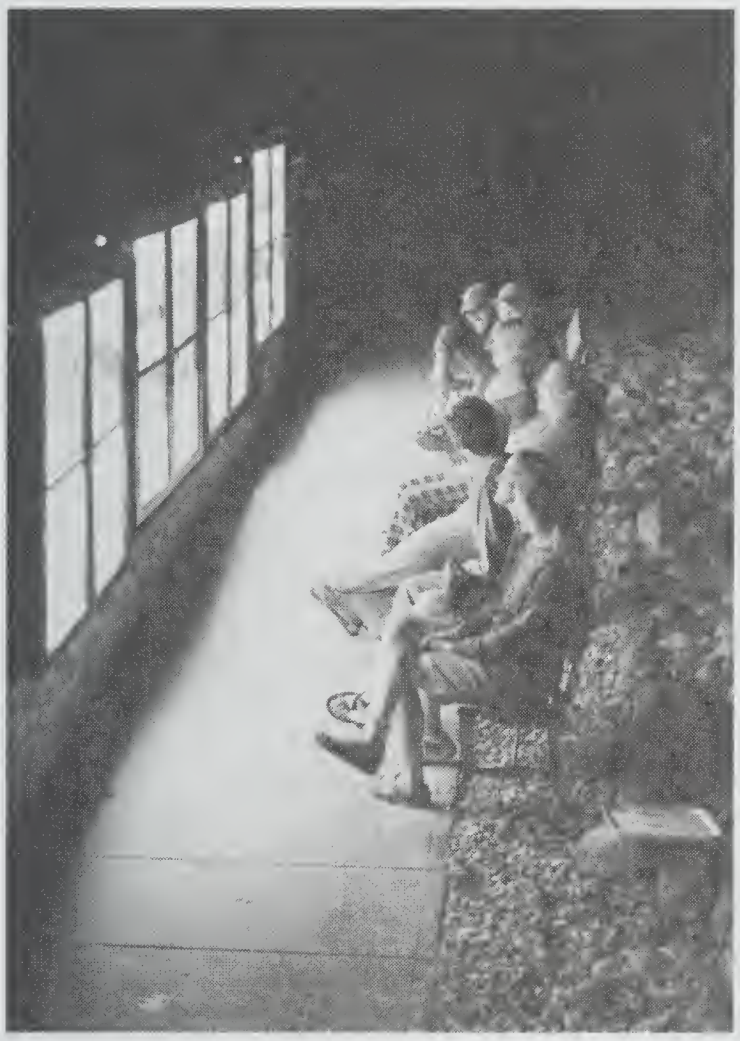

FIGURE 22. Students study Plant TV at night. Photo by M. Petru.

tective of these displays. At the end of each field trip, only Ed and the TA were allowed to unpack the plants from the vasculum, place them carefully into water bottles, and transfer them to plant TV with their proper typewritten name card (Fig. 21). Once in plant TV, no student was allowed to touch any of the plants, or even open the door to plant TV. Ever! Prior to quizzes and exams, students would set up camp at plant TV, often staring into the glow of the fluorescent lights late into the evening, creating mnemonics to remember each family and scientific name (Fig. 22). Who among his students could ever forget that Poison-ivy, *Toxicodendron radicans* (L.) Kuntze (now *T. rydbergii* (Rydb.) Greene), was the only plant in plant TV stored in a brown beer bottle (Fig. 21), and always appeared as unlucky #13 on the first quiz? Lucky #13 still appears on quizzes every year as a tribute to Ed.

Ed was a botanical monk. Ed did not suffer inexactitudes lightly. We remember an unknowing student commenting on the value of common names, to which Ed replied without hesitation, "Common names are for common people!" We confess to having used this expression many, many times in our own teaching (always crediting Ed, of course). It would be easy to interpret this as malicious, but that was never Ed's intent. And despite what many people thought, he was more aware of his manner than we expected. When teaching *Rubus parviflorus* Nutt., for example, he offered about its fruits—"People say they are too tart, but I have a tart tongue anyway." We came to appreciate that Ed had a somewhat monastic vision of learning and teaching plants. There was one way, and he saw the path clearly. Any deflection from that path–be it rain, "dreadful" deer-

FIGURE 23: Ed Voss in a scene repeated virtually every summer, leading students from the 1994 Boreal Flora class along the crest of the dunes near the "ghost forest," Grand Sable Dunes, Pictured Rocks National Lakeshore. Photo C. E. Hellquist

flies, delays while filing into the vans–was just that. His job was to get his students back on the path as quickly as possible to get on with the task at hand. When in the field, it was time to learn, study, and appreciate the plants and ecosystems of Michigan.

A final lasting lesson from Ed. Ed always finished the semester with one of the most meticulously worded, detailed exams any student had experienced. The exam always began with the instructions to follow the directions carefully (with an '!' for emphasis). The second part of the exam was a "spot quiz" of 100 representative plants from the course. The installation of this quiz was so large it could not be contained within Gates Lab, and spilled onto the dining hall tables. The final exam marked a transformation of sorts for most students—a transformation that is only characterized by the best biodiversity courses.

Ed's passion for botany and Michigan resonated with his students. Few teachers, for example, receive hand-stitched embroidered field shirts from their classes year after year (Figs. 15, 24). Of these cherished personal gifts Ed wrote (2008), ". . . one of my most-appreciated mementos of my teaching days is a series of shirts, personally embroidered for me with a depiction of some plant of particular interest to the class." The tradition began in 1977 with dwarf lake iris (*Iris lacustris* Nutt.) and was followed by 13 additional shirts stitched with notable species (Voss 2008) including Sand Dune Thistle (*Cirsium pitcheri* (Torr.) Torr. & A. Gray), Thimbleberry (*Rubus parviflorus* Nutt.), Lake Huron Tansy (*Tanacetum bipinnatum* (L.) Sch. Bip. *subsp. huronense* (Nutt.) Breitung),

FIGURE 24. The back of one of Ed's many embroidered gift shirts. Photo by C. Mom.

American White Waterlily (*Nymphaea odorata* Aiton), and *Chenopodium capitatum* (L.) Ambrosi.

Ed kept a record of every student he taught at UMBS (nearly 400), many with whom he maintained correspondence throughout the years (Voss 2008). Under his direction and mentorship, Ed helped these students make sense of the greenery around them, providing the keys to unlock the natural world (see Fig. 7). For many, including us, classes with Ed opened an entirely new dimension of wonder and discovery (Fig. 23). His instruction offered one of the most important lessons that a beginning student of evolution and ecology can learn, which is paraphrased so succinctly in the Chinese proverb: "Wisdom begins by calling things by their right names." Ed would often reflect this proverb in variations of "You can't understand the play unless you know the characters." Finally, Ed's students always came to understand that sound conservation began with sound taxonomy of the species of his beloved Great Lakes region. As Ed taught us, this is also the gateway to becoming an informed steward of our planet and the appreciation that we are but one small leaf on this grand Tree of Life (Fig. 24).

ACKNOWLEDGEMENTS

We thank Irene Crum, Cindy Mom, Mary Scholtens, Karie Slavik, and Bob Vande Kopple for their assistance locating information and pictures related to Ed's teaching at UMBS. Thanks also to Tony Reznicek and Rich Rabeler for their assistance and suggestions during preparation of the manuscript.

ED VOSS AND THE CONSERVATION OF MICHIGAN'S RARE FLORA

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Of Ed Voss's many contributions and accomplishments as a botanist, professor, and much lauded teacher, as amply recounted and celebrated in this volume, his role as an indefatigable leader in plant conservation is one that should not be forgotten. His dedicated work in protecting and conserving the rare flora of Michigan and the Great Lakes region is an important legacy that will endure, his selfless devotion in this regard serving as a model to all (see Fig. 25). Ed Voss contributed to, and fostered, rare plant conservation throughout his career in numerous ways, as will be described below. Moreover, he initiated his efforts well before the existence, or significant expansion, of many national, state, and local conservation organizations now known to lead in such pursuits. Voss's work commenced prior to the advent of Earth Day in 1970 and the subsequent use and proliferation of such well-known terms or concepts as "biodiversity", "biophilia" (Wilson 1984), or—more topically—"sustainability." His involvement in conservation also began long before formal studies in the emerging fields of conservation biology and ecosystem management helped to articulate the scientific rationale for conserving rare biota. It is therefore fitting and highly appropriate to honor Ed Voss's important work in rare plant and natural areas conservation by providing a brief overview and description of his particular contributions in these areas.

As to how he may have regarded his purposeful work in this arena, it is easy to surmise, to those who knew him well, that he considered his involvement in conservation efforts to be much less an obligation than a natural and logical extension of his scientific endeavors. Thus, this work was pursued with the same vigor and thoroughness as applied to the *Michigan Flora*. One of Voss's most important roles in rare plant conservation was his long-time service as a member of the Technical Advisory Committee for Plants, as appointed by the Michigan Department of Natural Resources (MDNR) Threatened and Endangered Species Program. Initiated in 1974 following passage of the Michigan Endangered Species Act (Public Act 203 of 1974[1]), the Technical Advisory Committee engaged Voss and his colleagues with the important task of drawing up Michigan's first Technical List of state endangered, threatened, and extirpated vascular plant species (encompassing pteridophytes, gymnosperms, and flowering plant taxa). Preparation of a state rare plant list was a ground-breaking task, yet the newly passed Michigan act provided

[1]Now re-codified as Part 365, Endangered Species Protection, of the Natural Resources and Environmental Protection Act, Act 451 of the Public Acts of 1994 (Michigan Compiled Laws 1994).

little specific guidance about how to do so. The act did note that in addition to the Department's own investigations and status determinations, it was given the charge to seek "other available scientific and commercial data, which may include consultation with scientists and others who may have specialized knowledge, learning, or experience" to help promulgate a rule for the listing of such species. In the absence of specific procedures and protocols, considerable credit is to be given to Dr. Sylvia M. Taylor, Michigan's first State Endangered Species Coordinator (lodged within the MDNR Wildlife Division), for realizing the need to establish both a procedural precedent as well as a methodology that would result in developing a credible, objective, and scientifically defensible Technical List capable of passing the periodic scrutiny of the Michigan Legislature. Enlisting the assistance of Dr. Warren H. Wagner, Jr. to serve as its first Chair, the initial Technical Advisory Committee for Plants was formed, of which Ed Voss was a critically important member. Voss monitored the University of Michigan herbarium (MICH) records for the committee, and also played the primary role in evaluating the status of aquatic flowering plants, in addition to providing guidance via his prodigious knowledge of the Michigan flora. His painstaking work to document the distribution of rare species and other potential candidate taxa was only a portion of his efforts, as he also carefully monitored the procedures and decisions of the committee as well (S. Taylor, pers. comm.). I can vouch for this after having had the distinct honor of serving with him for the last three of the six list reviews conducted by this committee. Voss's voice of reason, his airtight logic, and his unimpeachable recommendations contributed enormously to a review system that stands with high credibility to this day. It is also a testament to the breadth and depth of his floristic knowledge that Ed Voss was also sought out to serve on the state Rare Plant Advisory Committee for Ohio Department of Natural Resources, on which he participated from 1992 until 2012.

In addition to his work on rare plant committees, Ed Voss contributed to plant conservation through several other miscellaneous positions and activities. Notable contributions included the Citizens Advisory Committee for the Cyrus H. McCormick Experimental Forest, U.S. Forest Service (1969), the Science Advisory Committee of the Michigan Chapter of The Nature Conservancy (1992–2002), and the Board of Technical Advisors, Tip of the Mitt Watershed Council (1993–2012). Voss was an esteemed and long-time trustee for the Little Traverse Conservancy (1983–2012), also serving on their Stewardship Committee and providing assistance by conducting a number of special botanical surveys (T. Bailey, pers. comm.). Voss was also a highly dedicated and respected trustee for the Michigan Chapter of The Nature Conservancy for two six-year terms of service (1986–1992 and 1993–1999). In the last known version of his curriculum vitae (2002), Ed noted that he was a member of "25 or more local, regional, or national conservation and natural history organizations, including The Nature Conservancy, Michigan Nature Association, Sierra Club, Wilderness Society, National Audubon Society, Environmental Defense Fund, Little Traverse Conservancy, Tip of the Mitt Watershed Council, Michigan Natural Areas Council, Federation of Ontario Naturalists, Upper Peninsula Environmental coalition, etc. etc.". These many activities demonstrate his lifelong commitment to plant and natural area conservation, conducted during a vigorous professional career and a well occupied "retirement" that

including ongoing Michigan Flora work and brief teaching stints at the University of Michigan Biological Station (UMBS) in Pellston. Amidst these endeavors, however, Voss somehow managed to find time to contribute yet more through various kinds of outreach and education, such as delivering lectures to a wide diversity of groups and organizations, leading numerous field trips (such as to his beloved Grass Bay for The Nature Conservancy), and answering unending (and countless) questions about plants (especially with regard to identifications), the inquiries arriving in all the standard ways, via phone, U.S. mail, personal visits, and the subsequent onslaught of e-mail (though he reserved a particular aversion to e-mail attachments).

Ed Voss understood the need to identify and protect natural areas as an essential underpinning for the conservation of plants and all other organisms, as underscored by the large number of organizations he served and supported . It is notable that more than three decades ago he took a keen interest, while a member of the editorial board of *The Michigan Botanist*, in the publication of an extended special issue devoted entirely to an overview of all known, dedicated nature preserves in Michigan (Crispin 1980). Susan Crispin, a botany graduate student advised by Dr. John Beaman of Michigan State University (Beal-Darlington Herbarium, MSC), prepared a master's thesis devoted to such an overview, resulting in an unprecedented compilation and description of the natural areas of the state. Although he knew such a compilation would be highly dynamic through time, Voss felt it was essential to present this work, both as a touchstone for accomplishment as well as a measure of the considerable efforts that remain for us all. It was, in its day, a kind of gap analysis and report card. Crispin (1980) acknowledges Voss's "enormous assistance in editing and arranging publication," and once remarked to me that she was deeply impressed by the level of his enthusiasm for this paper and his passion and sense of urgency for bringing it to the readership of the journal and the conservation community. As eloquently summarized by Tom Bailey, the Director of the Little Traverse Conservancy, Ed Voss "was an amazing botanist, a dedicated conservationist, and a wonderful friend. When he disagreed about something, he was the embodiment of the Loyal Opposition, and always worked hard in service to the conservation cause." With the passing of Ed Voss, plant conservation has lost one of its staunchest champions, one who left the richest and most admirable of legacies and quietly taught us by his example and deed.

ACKNOWLEDGEMENTS

I am indebted to Sylvia Taylor for providing critical background information about the early work and organization of the state Technical Advisory Committee for Plants, and to Tom Bailey and Doug Pearsall for kindly verifying terms of service. I would also like to thank Tony Reznicek and Rich Rabeler for guidance and support.

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THE ROAD TO THE ISLES: REMINISCENCES OF ED VOSS AS DISSERTATION CHAIRMAN

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At this time twenty-five years ago, I was writing my dissertation. The energy, youthful enthusiasm, and purpose with which I entered The University of Michigan had not abated. Ann Arbor's cultural stimulation and academic environment remained unrivaled. I had served as a teaching assistant under notable faculty. Nonetheless, my utmost reason for pursuing a doctorate at U-M was to study under Edward G. Voss. No doubt, he stands highest among those who shaped my botanical career. As a teacher (Fig. 14), he grounded me in nomenclature, aquatics, and the flora of northern Michigan. As mentor and dissertation chair, he directed my research, shaped my writing, penned letters of recommendation, and served as an early reference on my resume. As a friend, he encouraged me during my early years as a college professor.

My passion for field botany and desire to teach at the college level developed while still an undergraduate in western New York State. Midway through that experience, a biology professor recommended (to those considering graduate school) picking a research organism which one would still love after five years of study. I tell my students that finding a dissertation committee chair with whom one can develop and maintain a cordial relationship is considerably more important.

My rapport with Ed developed during a summer at the University of Michigan Biological Station (UMBS) while still pursuing my Master's at Michigan State University. His invitation to take his Boreal Flora (Fig. 25) course came when he visited East Lansing to speak about upper Great Lakes islands at a Michigan Botanical Club meeting.

My research on the Nordhouse Dunes, a then proposed wilderness area, had intensified an interest in regional flora. Moreover, I had concluded that continued graduate study centered on floristics (within Michigan, at least) would most likely only happen under Ed's direction. My motivation to spend the summer at UMBS centered on learning more about him and demonstrating that I was worthy of graduate study under his direction. Ed probably saw it as a prime opportunity to evaluate me.

The respective insights into each other's personalities gleaned during that summer provided the foundation for our eventual collaboration on my dissertation research. In addition to taking Boreal Flora, I conducted an independent study of the flora of Round Island, another proposed wilderness area, in the Straits of Mackinac.

FIGURE 25. Boreal Flora, UMBS 1980. Photo by Gary Williams

Before heading to the Station, I had been forewarned that Ed was often brusque. My informant, however, recommended that I not let that rough exterior prevent me from knowing him better. Taking a cue from the 1973 film, *Paper Chase*, I read much of what Ed had authored soon after arriving at the Station. Among Ed's passions were environmental stewardship, biogeography, philology, and nomenclature. When he interspersed those subjects throughout his lectures and field trips, I noticed. To some taking Boreal Flora, Ed spoke in inscrutable parables. If so, I had discovered the key to their interpretation. One merely had to listen and anticipate what he would say next.

Ed subtly found ways to connect to his students. When discussing *Clintonia*, he would typically ask a student from New York State (were one present) to remind the rest of the class who DeWitt Clinton was. Such a seemingly random question about an Empire State governor makes greater sense in light of the alternate name of the Erie Canal; Clinton's Ditch. While on a joint collecting trip to Round Island, soon after hearing that I had a year of Greek as an undergraduate, he immediately proceeded to quote (in Greek!) the beginning of the Gospel of John. Fortunately, Professor Stockin had covered that material, thus by the time Ed had reached "*προς τον θεον,*" I recognized the quotation.

Ultimately, my habit of listening closely to what Ed said (and sometimes enduring a pun or a rant on the literal interpretation of a phrase or road sign) would pay off when he became my dissertation chair. By that summer's end, meanwhile, I was fully established in the flora of northern Michigan, increasingly

confident in conducting botanical inventories, and committed to pursuing research on Lake Michigan islands.

Ed and I had concluded, were I eventually accepted at U-M, he would oversee an investigation of the floras of the Manitou and Fox islands. He considered islands, with their readily defined boundaries, to be worthy of special consideration. Thus, within *Michigan Flora,* seven islands (or island groups) in the Great Lakes are mapped separately from their mainland counties. Leelanau County has two distinct groups: the Manitou Islands and the Fox Islands.

Although my entry into a PhD program in Ann Arbor would begin three years after that conversation, in the interim UMBS sought a primary investigator for a National Park Service-funded botanical survey of North and South Manitou. Fortuitously, Ed recommended me for the job. Thus, when I entered my doctoral program, I already had a season of field work *and* a working relationship with Ed.

Ed believed that the happiest graduate students were often the most productive. I thoroughly enjoyed my tenure in the U-M herbarium. I eagerly used page proofs of *Michigan Flora* while keying unknowns from my islands as well as from the mainland portion of Sleeping Bear Dunes National Lakeshore. Under Ed's direction I became more disciplined; more task-driven rather than time-driven.

Ed Voss personified persistence and precision. Words mattered. Just the right word or phrase mattered more. Creating clear prose was his personal obsession. Subsequently, my writing became more accurate. For instance, *further* referred to time; *farther* denoted distance. Hyphens were handy. Placing a hyphen between two dates automatically signified a range; one need not be encumbered using *to* and *from*. One could refer to *wind- and water-dispersed species*; *wind and water-dispersed species* might imply two-part dispersal. Similarly, whereas *Fox and Manitou islands* would signify two separate groups, *Fox and Manitou Islands* would refer to only one island group. Accuracy in plant identification was essential, yet my time-driven tendencies would inevitably surface. Ed, nonetheless, cared enough to convey lists of my misidentifications to keep my records current and to avoid subsequent mistakes. He could be gentle or sharp (often using ! or ?) depending on the egregiousness of the error. Among his terse comments:

> 3167 is *Linaria canadensis*, not *Lobelia kalmii* (which differs in having an inferior ovary, no spur on the corolla, and a big split down the middle of the upper lip).
>
> 3766 *Agrimonia striata* [not *gryposepala*—a nice record! It keys perfectly to *striata* in Mich. Flora; what went wrong?]
>
> 4718 *Bidens cernuus* [not c*onnatus*] . . . This is the only misidentified *Bidens* to have come through in at least 5 years. What key did you use and what eyes examined the specimen?

As far as I could tell, these and similar blunders did not interfere with our friendship. Ed was firm, yet forgiving.

Ed, unlike some committee chairs, did not insist dissertations be perfect. Ideally, opportunities to improve one's work would arise later during one's career. On the other hand, "one's work" assuredly encompasses more than a dissertation. Another recollection from Professor Stockin's Greek class applies here, "*A student is not above his teacher, but everyone who is fully trained will be like his teacher*" (Luke 6:40 NIV). In many respects, I am still Ed's student and I reflect his influence more than I realize. Among the habits that I do acknowledge: an insistence on clear writing, the necessity of prepping a field trip, and keeping accurate collecting records.

I also maintain a culinary tradition. During a Boreal Flora field trip to the Upper Peninsula, we fixed dinner over Coleman stoves at a roadside rest along Lake Michigan. That night's meal was a hamburger-based creation inspired at the conclusion of a collecting trip which Ed made to North Manitou Island in the 1950's. I pirated the recipe for "Manitou Mystery" while assisting in its preparation. Today, I continue to serve a version of it on nearly all my overnight field trips with students. Typically, the circumstances behind the meal's genesis plus my involvement with the Manitou Islands are recounted. This narrative also includes recalling a few noteworthy field trips when I have prepared it. From now on, I am sure that I will add a few words about the person who invented the meal. And who also inspired me.

ED VOSS—AS AN EDITOR

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Ed Voss founded *The Michigan Botanist*, with the first issue appearing 1962. It was "his" from the start. Not only did he edit submitted articles, he provided many book reviews, and started several regular features. *Michigan Plants in Print* was an annotated list of "significant literature relating to Michigan botany since the beginning of 1960"; installments of this feature appeared in 27 volumes of the journal (see list in the introductory article). *News of Botanists* included notes about faculty assuming new positions, graduate students completing degrees and assuming new positions, etc. He oversaw the editing and production of the first 15 volumes, handing over the editorial reigns to Howard Crum in 1977; the Club honored Ed for his service as the first editor with an award. He continued to serve as an advisor to the journal, remaining on the Editorial Board until his passing.

As many know, Ed was an editor's editor. He developed a command for the English language, no doubt fostered by his father's experiences in teaching Latin and Greek. Typos, incorrect usage, and factual errors were not for him. The editorial staff at the Ann Arbor News knew him well from the many letters to the editor that he penned over the years.

I (RKR) remember when I submitted my second paper to *The Michigan Botanist* around 1980. Although not the editor at the time, Ed reviewed the paper. His review was nearly as long as the paper—scary to a grad student, but the thoroughness made it a much better paper.

When I (RKR) became one of the co-editors of *The Michigan Botanist* in 1988, I knew that he always inspected the latest issue when it arrived. I always approached the release of another issue with trepidation—would the "O" in "Botanist" be precisely aligned over the Straits of Mackinac on the cover? Would Ed spot some needless typos? Would the fourth number of a volume be mailed during the same calendar year—Ed did notice the one time when that did not take place. Actually, having the founding editor watching likely made my products better!

Anyone who knew Ed was well aware that Ed "told it like it is"; no skirting an issue for him. Ed received a copy of a volume entitled *Manual of the Seed*

Plants of Indiana to review in 1989. One also readily knew when Ed did not like something. He started his review with "That whirring noise you hear in the background is Charles C. Deam [author of the 1940 *Flora of Indiana*] turning in his grave"—and it got worse. In fact, I had to add an editorial note at the end of his two-page review when it appeared in 1990—"This book has been withdrawn by the publisher." How many reviewers can claim that distinction?

I (TJR) always will remember, with great fondness and admiration for the man, the time I asked Dr. Voss to serve on my dissertation committee, as co-chairman. I had been having trouble working up the nerve to do so, because I had gotten the feeling that he had not been writing to any relatives about my work, at least not in a good way. So, I began very cautiously, but before I could get to the actual question, he announced, in that abrupt, loud, deep, clear, certain way of his, "No way!". Luckily, I had experienced this sort of thing before (my dad was comparably decisive), and so was not completely deterred, but I did proceed from that point even more cautiously in establishing that I had not yet asked him anything, and that if he would clarify just what he was refusing to do, it might be helpful. He responded that because he knew nothing about "species problems", he was not qualified to review my dissertation proposal. Now I was seriously concerned, because my intention had been to ask for much more than this. I responded with a very subdued, "Oh . . . uh, um, er, actually, I was intending to ask about something far more involved: that you not only review my proposal, but serve on my dissertation committee, as well . . . and that you not only serve on it, but serve on it as, um, er . . . co-chairman." Somehow, that did not send Dr. Voss heading for the hills, possibly because I had quickly followed those remarks with an explanation that I didn't need him to know anything about "species problems" per se, but rather that I simply wanted my work to benefit from what I had observed to be his tough, thorough, rigorous, honest, fair, and nearly always correct scrutiny.

I (TJR) had this experience in mind as I handed Dr. Voss an early draft of my dissertation, while standing in his office, marveling over the fact he had a little stand for his phone so he could make use of the desk surface underneath it. We chatted about various problems I had had along the way in addressing my dissertation topic, as Dr. Voss paged through what I had handed him. At one point he interrupted something I was saying to point out that something I had written near the end contradicted something I had written a couple of hundred pages earlier. He was correct about the contradiction, of course, and this, together with the fact that he had noticed it so easily and so readily, made me realize I had done the right thing several years earlier in standing in there until he reversed his initial position and agreed to serve on my dissertation committee, as co-chairman.

A couple years later, I (TJR) handed over to Dr. Voss a reprint of the first publication to result from my post-doctoral gig, which was to prepare treatments for the Generic Flora of the Southeastern United States. For what was the first time in my recollection, Dr. Voss seemed pleased to have something I had given him. As he slowly went through it, handling each page in a way that reminded me of the way he would hold up a plant about which he was teaching, with delicacy and appreciation, he said that he loved that series of papers, because "every single mark on every single page means something," which I took as the ultimate

compliment for my editors, and initially as a comment that had very little to do with me. However, as it turned out, it had a lot to do with me, in the sense that it had a large, important impact on my development as an editor, as well as author: it planted in my brain, just as firmly and significantly, relatively speaking, as that flag was planted atop Mount Suribachi, that each mark does matter, both in its own right and in terms of the effect it has on higher levels of organization: the groupings of marks into words, phrases, keys, descriptions, treatments, and floras.

This thought occurred to me (TJR) countless times over the past 25 years, over and over again, as I did my part in transforming manuscripts that had been submitted by hundreds of authors into pieces that would fit together into a much larger whole: The Jepson Manual—Higher Plants of California, and just recently its Second Edition (TJM2).

For the past couple of months, I (TJR) have been making corrections to TJM2. That they number in the hundreds has not been the most satisfying news, but it has gotten me to think yet again about the great concern that Dr. Voss demonstrated so many years ago for all those marks that are supposed to mean something. Although I am sure that there would have been many fewer corrections had Dr. Voss himself been more directly involved with our project (i.e., more directly involved than having inspired and trained its Scientific Editor), I was heartened by something that we determined just a few days ago: there are over 10 million marks in TJM2 (if spaces are counted), so the fact that a few hundred of them are incorrect is . . . completely unacceptable! As (nearly) always, yes, you are correct, Dr. Voss; we needed you, we thank you, and we will miss your influence.

EDWARD G. VOSS, AN ACCOMPLISHED ENTOMOLOGIST

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Edward Voss' interest in entomology developed early in life, certainly in large part due to his consistent exposure to nature and interesting habitats each summer at his family's summer cottage in Mackinaw City, MI. Ed's parents encouraged his natural history pursuits, allowing the rearing of caterpillars and collections of plants and insects to accumulate in the cottage and at home in Toledo, OH. Despite a strict bedtime, Ed was allowed special dispensation to set an alarm and get up late at night to go out and collect moths at lights. In addition, he was regularly allowed to ride his bicycle several miles out of town to favorite collecting locations, e.g. Cecil Bay in Emmet Co., MI and Stimson Rd. in Cheboygan Co., MI, both mentioned in his listing of the butterflies of the area (Voss 1954). He also took his entomological interest with him to Camp Miniwanca in Oceana Co., MI where he spent a week or two for several summers. His counselors there also allowed Lepidoptera collecting, resulting in several interesting records from the Lake Michigan shoreline. I was gratified to see that the camp still existed when I passed by while conducting an extensive survey of the Lake Huron Locust on Great Lakes dunes. This early fascination turned into an award winning project when, in 1946, Ed was chosen by the Science Clubs of America as one of the 300 high school senior students with the most outstanding promise and ability in science based on his performance on a 3-hour exam and an essay about a scientific project, in Ed's case, "A Biological Survey" of the Mackinaw City area, focusing primarily on butterflies. This was obviously a very prescient choice for the award on the part of the Science Clubs of America.

Ed took his interest in entomology to college at Denison University from 1946 to 1950. Here he met and worked with the nationally known skipper expert, Arthur Ward Lindsey, who had published extensively on this group of Lepidoptera (Lindsey 1921; Lindsey *et al.* 1931). This collaboration resulted in a senior thesis examining the phylogeny of the skippers (Hesperioidea) worldwide (Voss 1952). He used specimens from Lindsey's extensive collection and also borrowed specimens from around the world to complete tedious dissections and an analysis of morphology in the group. Several others have worked on this group subsequently (e.g. Evans 1937, 1949, 1951, 1952, 1953, 1955; and Watson 1893 before him) and the morphological diversity of the group has always made determining relationships difficult. When molecular techniques were finally applied to the problem along with the morphological evidence (Warren *et al.*

2009), Ed's original phylogeny was found to be very close to the currently accepted hypothesis.

Ultimately, Ed's interests transitioned into a greater focus on botany as a graduate student at the University of Michigan (graduating with a Ph.D. in 1954), but he always remained actively involved with entomology, particularly studying the Lepidoptera of northern Michigan. Shortly after arriving at Michigan and taking on the career project of the "Michigan Flora," he was again actively publishing on butterflies and moths. Over a period of many years, he wrote a series of papers cataloging all the known species of butterflies and other Macrolepidoptera, the larger moths, of the Emmet Co. and Cheboygan Co. region (Voss 1954, 1970, 1981, 1983, 1991, 2002). This has proven to be one of the most complete regional surveys in North America, with Ed having recorded 747 species in 19 families (as currently defined). I have since taken over the survey and started work on listing the Microlepidoptera of the region, so far adding 187 species in the Pyralidae and Crambidae (Scholtens 1996) as well as tallying 509 species in other families (Scholtens unpublished data), for a current total list of 1443 species in the region. Perhaps the most comparable regional survey at a similar latitude was one done by Procter on Mt. Desert Island in Maine (Procter 1946) in which he recorded 1479 species, so the Voss-initiated survey effort compares very favorably. My sampling over 25 years, during and since the publication of the Voss lists, has added very few additional species in the families that he covered, confirming the thoroughness of his original work.

Ed's sampling for this effort concentrated on the area around Mackinaw City and the property of the University of Michigan Biological Station, where he was a student and teaching assistant from 1949–1953 and taught botany courses from 1963 through 1998 and again in 2003. An extensive knowledge of the botany and habitats of the region helped him seek out other unique areas for sampling such as fens, bogs, and dunes. Notes about the occurrence of species in these habitats pepper the accounts in his papers. I regularly tapped into that expertise as I went looking for particular species of butterflies and moths, and I have often based field trip locations for my summer Biology of Insects and Ecology classes on this wealth of information.

Voss' collecting and listing of Lepidoptera had an impact on entomology in several ways, particularly on our knowledge of the natural history of northern Michigan. Ed accumulated an extensive collection of Michigan Lepidoptera kept at his cottage in Mackinaw City (Fig. 26), and donated many specimens to the University of Michigan Museum of Zoology, the Michigan State University Collection and the collection at the University of Michigan Biological Station. The remainder of his collection will be deposited at Michigan State University. His listings have provided an invaluable dataset recording the occurrence of uncommon or rare species (e.g. Bates' crescent: *Phyciodes batesi*, dusted skipper: *Atrytonopsis hianna*, and cobweb skipper: *Hesperia metea*), unusual vagrants (e.g. California tortoiseshell: *Nymphalis californica* and black witch: *Ascalapha odorata*) (Voss 1950), and local eruptions of populations (e.g. galium sphinx: *Hyles gallii*). His papers include excellent documentation of habitat associations and specific localities where species were found.

As I have discovered subsequently, these data are also crucial as we start trying to understand changes in species ranges and abundances due to invasive species and climate change. Comparisons between Ed's collection records and mine in recent years have documented the northward migration of the dion skipper, *Euphyes dion*, a wetland skipper previously known from the middle lower peninsula, but now found north to the Straits of Mackinac, and the retreat northward of at least two butterflies, the greenish blue, *Plebejus saepiolus*, (evidently retreating throughout its eastern range) and the branded skipper, *Hesperia comma*, still found in the Upper Peninsula. Both of us witnessed the invasion of the gypsy moth, *Lymantria dispar*, during the 1990s. Even though northern Michigan experienced only a single large, extended defoliation event caused by this European introduction, the legacy of its introduced enemies has apparently left a lasting effect. In the last decade and a half, other large moths, particularly Saturniidae, that Ed recorded as common (and still common in the 1980s and early 1990s), have become very rare or locally extirpated, probably due to parasitism by the introduced tachinid fly *Compsilura concinnata*. These include the imperial moth, *Eacles imperialis*, the Io moth, *Automeris io*, and the Polyphemus moth, *Antheraea polyphemus*. Some of these same species suffered the same fate in the Northeast (Boettner *et al.* 2000; Goldstein 2010), but populations there have since shown signs of recovery. We have yet to note any positive trend of recovery in northern Michigan.

Ed was an excellent observer and had a trained taxonomic eye (both in botany and entomology). Generally, he did not try to obtain long series of species, but worked primarily on documenting the diversity of the Lepidoptera in the region. His ability to recognize fine differences among difficult species groups made for a discerning eye as he collected specimens. His nearly photographic memory was also valuable as he chose what to collect. He kept copious notes on his observations, and occasionally turned these observations into short notes about the biological interactions of insects, such as a very interesting paper on the pollination of blunt-leaf orchids by pyralid (*senso lato*) moths (Voss & Riefner 1983). He also regularly incorporated these observations into his teaching in botany classes, helping students learn about pollination systems and the influence of herbivores on plants.

During his career, Ed built collaborations with many different entomologists. Lindsey was probably his first major entomological contact, but he soon met many other well-known lepidopterists, many through the Lepidopterists' Society, in which he was a charter member and just recently elected as an honorary life member. At the University of Michigan, his colleagues included W. H. Wagner, Jr., another multidisciplinary biologist who was a professor in botany but also collected and published on Lepidoptera, including a note about the occurrence of two rare species in northern Michigan (Voss & Wagner 1956). Ed became an important entomologist in the state and regularly consulted with other entomologists from around the state, particularly through the Michigan Entomological Society. He was also a longtime member of the Ohio Lepidopterists and the Kentucky Lepidopterists, and built a large library of Lepidoptera literature based on his contacts across the continent.

Edward Voss' career will, of course, be marked primarily by the completion

FIGURE 26. Ed Voss's laboratory space in the family cottage where he did his Lepidoptera work, and also some plant work in the summers. Photo by Ed Voss, 18 June 1990.

and publication of the *Michigan Flora*, a monumental achievement by itself. He completed this effort shortly before his retirement in 1996. In typical Voss fashion, he also planned his publication of the Lepidoptera lists of northern Michigan, and finished the final planned installment shortly after his retirement (Voss 2002). Ed's was a well-planned and well-lived life and career with a great influence in two complementary spheres of biology, botany and entomology.

Appropriately, Ed's first visit to the Biological Station, a place where he spent most of the entomological part of his career, was in 1938, when, at age 9, his father took him to the Station on visitor's day and bought him his first insect pins.

Likewise, his life was nicely bookended by a trip to the Biological Station on visitor's day in 2011. He spent the day speaking with colleagues, visiting friends, and enjoying one of the most beloved places of his life and career.

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On the cover: *Ed Voss camping on Cusino Lake, near Lake Superior with his Jeep in Aug. 1966. Photo by John Russell.*

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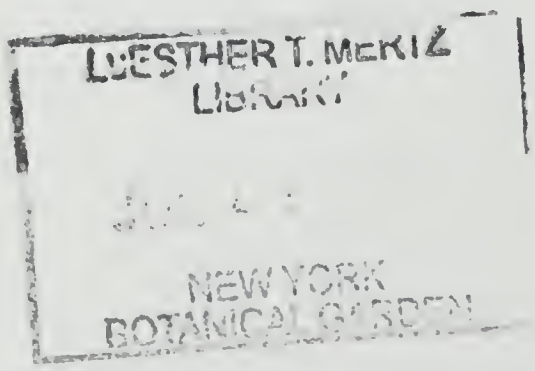

ASSESSMENT OF A NOVEL RECLAMATION EFFORT IN GRAND MERE STATE PARK

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ABSTRACT

The Great Lakes sand dunes, the largest system of freshwater sand dunes in the world, are a natural resource with both ecological and economic value. In 2000, the Michigan DNR proposed a novel reclamation plan to restore one of these dunes after being mined. This dune area, the former Manley-Peters Sand Mine (MPSM), is located in Grand Mere State Park in Berrien County, Michigan. Local genotypes of 115 native dune species were planted within seven microhabitats over a three- to four-year timeframe. As of 2011, the vascular plant flora at the MPSM reclamation site consists of 150 taxa, representing 50 families. A 56.5% post-planting survival was observed for the originally planted species from the reclamation plan, and 58 native species have established on their own at the site. Of these native volunteers, *Carex umbellata* was a new report for Berrien County's flora. The 2011 study has provided a baseline assessment of species richness for use in long-term monitoring of this reclaimed sand dune area.

KEYWORDS: Grand Mere State Park, Great Lakes, Michigan flora, reclamation, sand dunes

INTRODUCTION

Michigan benefits from many natural resources, some of which are economically important, while others have ecological value. As part of the largest freshwater dune system in the world, the Lake Michigan sand dunes provide suitable habitat for many plants and wildlife, giving the dunes high ecological worth. Lake Michigan's dunes are particularly valuable in industry because they contain nearly pure quartz mineral content (Wilson, 2001), and they have been mined for automobile foundries since 1910 because of the sand's exceptional purity, grain size, and texture (Ayers *et al.*, 2001).

The Manley-Peters Sand Mine (MPSM), located in Grand Mere State Park of Berrien County, Michigan, has been intermittently active since 1965, when the Manley Brothers began operations. The passing of the 1976 Sand Dune Protection Act ended unmonitored mining of sand dunes and required companies to reclaim used dunes. After several years of inactivity at the Peters mine, the Manley Brothers requested a permit from the Michigan Department of Natural Resources (MDNR) in 1979 to continue mining. After a couple of legal battles, the Manley Brothers and the MDNR agreed to a Progressive Cell-Unit Mining and Reclamation Plan (Palmgren, 2004).

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TechniSand, Inc. bought the mine from the Manley Brothers in 1999. A 1999 letter of agreement outlined the financial responsibilities of both TechniSand, Inc. and the MDNR State Park Stewardship Program in restoring the mine back to a natural area. Under a new permit with the MDNR (1999), TechniSand (now Fairmount Minerals) was allowed to harvest sand from the site until June 17, 2003. The company promised to cooperatively implement a plan with MDNR to reclaim the dunes which included mining below the water table to add to habitat diversity for the reclamation effort (Palmgren, 2004).

Previous dune stabilization projects in Michigan have used *Ammophila breviligulata* (beach grass) monocultures in their reclamation protocols (Woodhouse, 1982), as beach grass prevents dune loss due to wind and water erosion. However, a novel reclamation approach was proposed by MDNR at MPSM to develop "functioning ecosystems" by establishing seven different planting zones, or microhabitats (Palmgren, 2004). The seven microhabitats established at the MPSM reclamation site were steep slope, gentle slope, prairie, wetpanne, wetland shelf, shallow water, and deep water (Fig. 1). A detailed planting schedule comprised of native dune taxa was outlined by Palmgren (2000) and then revised in 2004 after the reclamation effort was underway. Over 550 plant taxa have been documented in Grand Mere State Park, and local genotypes of 115 of these species (of plugs, seedlings, seeds, shrubs, transplants and/or tubers; see Appendix I) were planted throughout the 40-acre site, according to the restoration plan (Palmgren, 2004; 2000).

In 2004, we began visits to the site while the reclamation was in progress, and a follow-up evaluation took place in 2008 after the plantings had time to establish. With comparison of the revised 2004 planting list from MDNR, the primary objective of our 2011 study was to generate an official checklist of vascular plants at the MPSM reclamation site to assist in determining post-planting survival of the original plantings. Second, we estimated species richness for the site overall, as well as for five (steep slope, gentle slope, prairie, wetpanne, and wetland shelf) of the seven microhabitats through detailed surveys and additional quadrat analyses. Furthermore, the 2011 survey of the MPSM reclamation site flora will provide a baseline assessment for use in long-term monitoring of this novel reclamation effort in Grand Mere State Park.

MATERIALS AND METHODS

A Michigan DNR permit (#RD-SU-2011-010) was granted for field work and the collection of plants at the MPSM reclamation site. From May to September of 2011, ten collecting trips were made to the site in Grand Mere State Park to document the existing flora. Each species was recorded as part of the original reclamation plan, as a newly established native of Michigan's flora, or as a newly established adventive (i.e., non-native) species. Post-planting survival of the planted species from the MDNR list was calculated. Most of the documented species were collected as voucher specimens and deposited in the Hillsdale College Herbarium (HLSD). The *Michigan Flora* website (http://michiganflora.net) was used to assign native or adventive rankings to the taxa that had established at the site, and taxonomy for all species follows that of the website too. Species were also recorded specifically for the steep slope, gentle slope, prairie, wetpanne, and wetland shelf microhabitats across the entire reclamation area to estimate species richness for each.

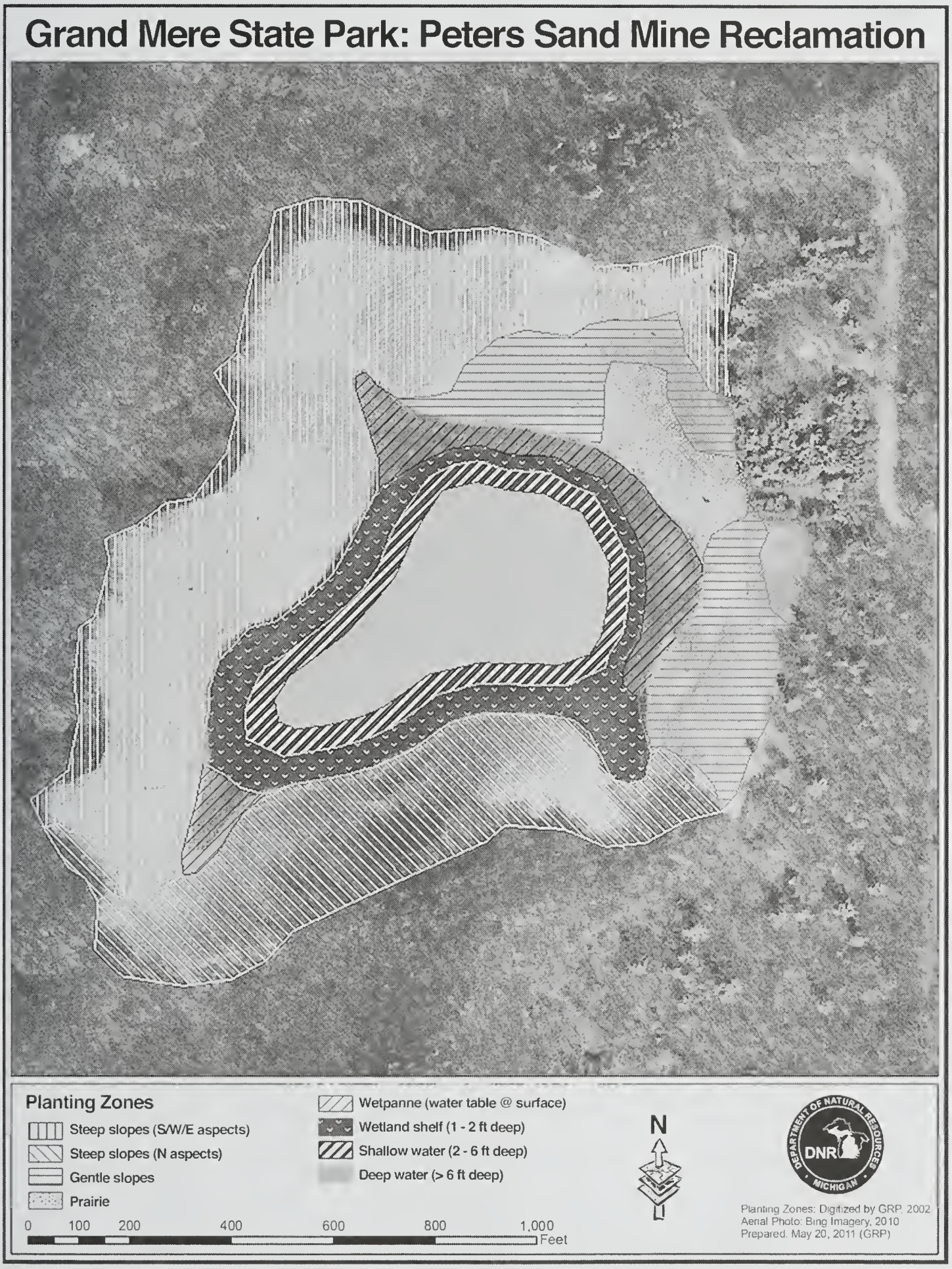

FIGURE 1. The Manley-Peters Sand Mine reclamation area post-mining showing the planting zones, or microhabitats. (Map courtesy of Glenn Palmgren; Graphic assistance provided by Angela Lashaway.)

FIGURE 2. Photo of the reclamation in progress in 2004. Gentle slope habitat is in the foreground adjacent to the wetpanne habitat, while steep slopes occupy the background. (Photo by Ranessa Cooper.)

RESULTS

The MPSM reclamation site has changed considerably since our first visits in 2004 (Fig. 2), and it is evident that the vegetation is denser in the steep slope, gentle slope, and wetpanne habitats (Figs. 3, 4). The 2011 survey revealed that 150 vascular plant species occupy the site, representing 50 families (Table 1). The presence of *Carex umbellata* (sedge) at the MPSM reclamation site represents a new report for the native flora of Berrien County. Another native, *Juncus articulatus* (jointed rush) is new to the *Michigan Flora Online* for Berrien County, although it was previously reported from there by the *Plants of the Chicago Region* (Swink and Wilhelm, 1994).

In Palmgren's (2004) revised planting list, 115 species were planted across the site among seven zones, or microhabitats (see also Appendix I). In the five microhabitats surveyed here, 65 planted species were documented (Table 1), resulting in a 56.5% post-planting survival from the original planting list. The steep slopes, gentle slopes, prairie, and wetpanne maintained at least 41% of the taxa originally planted in each microhabitat, while the wetland shelf had 35.7% of its originally planted species still persisting (Table 2).

FIGURE 3. Photo of the reclamation area in 2008. Gentle slope habitat is in the foreground adjacent to the wetpanne habitat, while steep slopes occupy the background. Vegetation is denser compared to that seen in 2004. (Photo by Ranessa Cooper.)

FIGURE 4. Photo of the reclamation area in 2011. Gentle slope habitat is in the foreground, while steep slopes occupy the background. Vegetation is denser compared to previous years. (Photo by Ranessa Cooper.)

TABLE 1. A 2011 checklist of vascular plants (including microhabitat occurrence) at the former Manley-Peters sand mine in Grand Mere State Park.

MAJOR TAXONOMIC GROUP Family—Species* [Microhabitat† presence—Status‡]
SEEDLESS VASCULAR PLANTS
Dennstaedtiaceae *Pteridium aquilinum* (L.) Kuhn (Bracken fern) [GS—Planted]
Equisetaceae *Equisetum arvense* L. (Common horsetail)* [GS, W—Native]
Equisetum laevigatum A. Braun (Smooth scouring rush)* [GS, W—Native]
GYMNOSPERMS
Cupressaceae *Juniperus communis* L. (Common juniper; ground juniper)* [SS—Planted]
Juniperus virginiana L. (Red-cedar)* [SS—Native]
Pinaceae *Pinus strobus* L. (White pine)* [SS—Planted]
ANGIOSPERMS
Adoxaceae *Viburnum acerifolium* L. (Maple-leaved viburnum)* [SS, P—Planted]
Alismataceae *Alisma* sp. (Water-plantain)* [W—Planted]
Sagittaria latifolia Willd. (Wapato, duck-potato, common arrowhead)* [WS—Planted]
Anacardiaceae *Rhus typhina* L. (Staghorn sumac)* [SS—Native]
Toxicodendron radicans (L.) Kuntze (Poison-ivy) [SS—Native]
Apocynaceae *Apocynum cannabinum* L. (Indian-hemp)* [SS—Native]
Asclepias incarnata L. (Swamp milkweed)* [W—Planted]
Asclepias syriaca L. (Common milkweed)* [SS, GS, P—Native]
Asteraceae *Ambrosia artemesiifolia* L. (Common ragweed)* [SS—Native]
Anaphalis margaritacea (L.) Benth. & Hook. (Pearly everlasting)* [W—Native]
Arnoglossum atriplicifolium (L.) H. Rob. (Pale Indian plantain)* [GS—Planted]
Artemisia campestris L. (Wild wormwood)* [SS, GS, P, W—Planted]
Artemisia vulgaris L. (Mugwort)* [SS, GS—Adventive]
Bidens cernua L. (Nodding beggar-ticks)* [W—Planted]
Centaurea stoebe L. (Spotted knapweed)* [GS—Adventive]
Cirsium arvense (L.) Scop. (Canada thistle, field thistle)* [W—Adventive]
Cirsium muticum Michx. (Swamp thistle)* [W—Planted]
Conyza canadensis (L.) Cronq. (Horseweed)* [W—Adventive]
Coreopsis tripteris L. (Tall tickseed, tall coreopsis)* [P, W—Planted]
Erigeron annuus (L.) Pers. (Daisy fleabane)* [SS, GS, W—Native]
Erigeron philadelphicus L. (Common fleabane, Philadelphia fleabane)* [W—Native]
Eupatorium perfoliatum L. (Boneset)* [GS, W—Planted]
Euthamia graminifolia (L.) Nutt. (Grass-leaved goldenrod)* [SS—Planted]
Helianthus divaricatus L. (Woodland sunflower)* [GS—Native]
Hieracium caespitosum Dumort. (King devil, yellow hawkweed)* [P—Adventive]
Hieracium flagellare Willd. (Whip-lash hawkweed)* [GS—Adventive]
Hypochaeris radicata L. (Cat's ear)* [P—Adventive]
Krigia virginica (L.) Willd. (Dwarf dandelion)* [SS, GS, P—Native]
Rudbeckia hirta L. (Black-eyed susan)* [GS, W—Planted]
Scorzoneroides autumnalis (L.) Moench (Fall-dandelion)* [W—Adventive]
Solidago altissima L. (Tall goldenrod)* [SS—Native]
Solidago nemoralis Aiton (Gray goldenrod, old-field goldenrod) [SS—Planted]
Solidago rugosa Mill. (Rough-leaved goldenrod)* [W—Native]

(Continued)

TABLE 1. (Continued).

MAJOR TAXONOMIC GROUP Family	Species* [Microhabitat† presence—Status‡]
Asteraceae (cont.)	*Symphyotrichum dumosum* (L.) G. L. Nesom (Bushy aster)* [W—Native]
	Symphyotrichum lateriflorum (L.) Á. Löve & D. Löve (Calico aster)* [GS—Native]
	Symphyotrichum pilosum (Willd.) G. L. Nesom (Frost aster, hairy aster)* [SS—Planted]
	Tragopogon dubius Scop. (Goat's beard)* [SS, GS, P—Adventive]
	Vernonia missurica Raf. (Missouri ironweed)* [GS—Planted]
Boraginaceae	*Lithospermum caroliniense* (Walter) MacMill. (Hairy puccoon, yellow puccoon, plains puccoon)* [P—Planted]
Brassicaceae	*Arabidopsis lyrata* (L.) O'Kane & Al-Shehbaz (Sand cress)* [SS—Native]
	Lepidium campestre (L.) R. Br. (Field cress)* [W—Adventive]
	Lepidium virginicum L. (Common peppergrass)* [P—Native]
Cactaceae	*Opuntia humifusa* (Raf.) Raf. (Prickly-pear)* [GS—Planted]
Campanulaceae	*Campanula rotundifolia* L. (Bluebell, harebell)* [P—Planted]
	Lobelia cardinalis L. (Red lobelia, cardinal-flower)* [W—Planted]
	Lobelia kalmii L. (Kalm's lobelia, brook lobelia, bog lobelia)* [P, W—Native]
	Lobelia siphilitica L. (Great blue lobelia)* [W—Planted]
Caryophyllaceae	*Cerastium semidecandrum* L. (Small mouse-ear chickweed)* [GS—Adventive]
	Saponaria officinalis L. (Bouncing bet, soapwort)* [SS—Adventive]
Ceratophyllaceae	*Ceratophyllum demersum* L. (Coontail)* [WS—Native]
Cleomaceae	*Polanisia dodecandra* (L.) DC. (Clammy-weed)* [GS—Native]
Commelinaceae	*Tradescantia ohiensis* Raf. (Common spiderwort)* [GS, P—Planted]
Cornaceae	*Cornus drummondii* C. A. Mey. (Rough-leaved dogwood)* [SS—Native]
	Cornus sericea L. (Red-osier)* [SS—Planted]
Cyperaceae	*Carex comosa* Boott. (Sedge)* [WS—Planted]
	Carex crinita Lam. (Sedge)* [WS—Native]
	Carex flava L. (Sedge)* [W—Planted]
	Carex hystericina Willd. (Sedge)* [W—Planted]
	Carex lurida Wahlenb. (Sedge)* [W—Planted]
	Carex muehlenbergii Willd. (Sedge)* [GS, W—Native]
	Carex pensylvanica Lam. (Sedge)* [W—Planted]
	Carex stricta Lam. (Sedge)* [W—Planted]
	Carex suberecta (Olney) Britton (Sedge)* [W—Planted]
	Carex umbellata Willd. (Sedge)* [GS—Native]
	Cyperus schweinitzii Torr. (Rough sand sedge)* [SS, GS—Native]
	Cyperus strigosus L. (Long scale nut sedge)* [W—Native]
	Eleocharis erythropoda Steud. (Spike-rush)* [W—Native]
	Eleocharis obtusa (Willd.) Schult. (Spike-rush)* [W—Native]
	Schoenoplectus acutus (Bigelow) Á. Löve & D. Löve (Hardstem bulrush)* [W, WS—Planted]
	Schoenoplectus pungens (Vahl) Palla (Threesquare)* [W—Planted]
	Scirpus cyperinus (L.) Kunth (Wool-grass)* [W—Planted]
Elaeagnaceae	*Elaeagnus umbellata* Thunb. (Autumn-olive)* [SS—Adventive]
Euphorbiaceae	*Croton glandulosus* L. (Tooth-leaved croton)* [SS—Adventive]
Fabaceae	*Medicago lupulina* L. (Black medick)* [GS—Adventive]
	Melilotus albus Medik. (White sweet-clover)* [GS—Adventive]
Fagaceae	*Quercus alba* L. (White oak)* [SS, GS—Planted]
	Quercus rubra L. (Red oak)* [SS, GS—Planted]
	Quercus velutina Lam. (Black oak)* [SS, GS, P—Planted]
Gentianaceae	*Sabatia angularis* (L.) Pursh (Rose-pink; rose gentian)* [W—Planted]
Hamamelidaceae	*Hamamelis virginiana* L. (Witch-hazel)* [SS—Planted]

(Continued)

TABLE 1. (Continued).

MAJOR TAXONOMIC GROUP Family	Species* [Microhabitat† presence—Status‡]
Hydrocharitaceae	*Elodea canadensis* Michx. (Common waterweed)* [WS—Native]
Hypericaceae	*Hypericum kalmianum* L. (Kalm's St. John's-wort)* [W—Planted]
Juncaceae	*Juncus alpinoarticulatus* Chaix (Rush)* [W—Planted]
	Juncus articulatus L. (Jointed rush)* [W—Native]
	Juncus balticus Willd. (Rush)* [W—Planted]
	Juncus brachycephalus (Engelm.) Buchenau (Rush)* [W—Planted]
	Juncus canadensis Laharpe (Canadian rush)* [W—Native]
	Juncus effusus L. (Soft-stemmed rush) [W, WS—Planted]
	Juncus torreyi Coville (Torrey's rush)* [W—Planted]
Lamiaceae	*Lycopus americanus* Muhl. (Common water horehound)* [SS, GS, P, W—Planted]
	Monarda punctata L. (Dotted mint, horse mint)* [GS—Planted]
Lauraceae	*Sassafras albidum* (Nutt.) Nees (Sassafras)* [SS—Native]
Lemnaceae	*Lemna* sp. (Duckweed) [W, WS—Native]
Lentibulariaceae	*Utricularia vulgaris* L. (Common bladderwort)* [WS—Native]
Magnoliaceae	*Liriodendron tulipifera* L. (Tulip tree) [GS—Planted]
Moraceae	*Morus alba* L. (White mulberry, Russian mulberry)* [SS—Adventive]
Nymphaeaceae	*Nymphaea odorata* Aiton (Sweet-scented waterlily) [WS—Planted]
Oleaceae	*Fraxinus americana* L. (White ash)* [SS—Native]
Onagraceae	*Oenothera oakesiana* (A. Gray) S. Watson & J. M. Coult. (Evening-primrose)* [W—Native]
	Oenothera parviflora L. (Evening-primrose)* [GS—Native]
Orobanchaceae	*Agalinis purpurea* (L.) Pennell (Purple false foxglove)* [W—Native]
Poaceae	*Ammophila breviligulata* Fernald (Beach grass, marram grass)* [SS, GS—Planted]
	Agrostis gigantea Roth (Redtop)* [P—Adventive]
	Bromus japonicus Murray (Japanese brome)* [GS—Adventive]
	Bromus tectorum L. (Downy chess, cheat grass)* [SS, GS, P, W—Adventive]
	Calamagrostis canadensis (Michx.) P. Beauv. (Blue-joint)* [WS—Planted]
	Dichanthelium commutatum (Shult.) Gould (Panic grass)* [GS, P—Native]
	Dichanthelium commonsianum (Ashe) Freckmann (Panic grass)* [P—Native]
	Dichanthelium latifolium (L.) Harvill (Broad-leaved panic grass)* [GS, P—Native]
	Dichanthelium oligosanthes (Schult.) Gould (Panic grass)* [P—Native]
	Elymus canadensis L. (Canada wild rye)* [SS, GS, P—Planted]
	Elymus repens (L.) Gould (Quack grass)* [GS, P—Adventive]
	Koeleria macrantha (Ledeb.) Schult. (June grass)* [P—Planted]
	Panicum virgatum L. (Switch grass)* [GS, P—Planted]
	Poa compressa L. (Canada bluegrass)* [GS—Adventive]
	Poa pratensis L. (Kentucky bluegrass)* [GS—Adventive]
	Schizachyrium scoparium Michx. (Little bluestem)* [P—Planted]
	Vulpia octoflora (Walter) Rydb. (Six-weeks fescue)* [SS—Native]
Polygonaceae	*Fallopia cilinodis* (Michx.) Holub (Fringed false buckwheat)* [SS—Native]
	Rumex acetosella L. (Red sorrel, sheep sorrel)* [SS, GS, P—Adventive]
Potamogetonaceae	*Potamogeton illinoensis* Morong (Illinois pondweed)* [WS—Native]
	Potamogeton natans L. (Pondweed)* [WS—Native]
	Potamogeton nodosus Poir. (Pondweed)* [WS—Planted]
	Stuckenia pectinata (L.) Börner (Sago pondweed)* [WS—Planted]
Ranunculaceae	*Ranunculus longirostris* Godr. (White water crowfoot)* [WS—Native]

(Continued)

TABLE 1. (Continued).

MAJOR TAXONOMIC GROUP Family	Species* [Microhabitat† presence—Status‡]
Rosaceae	*Fragaria virginiana* Mill. (Wild strawberry)* [GS—Native]
	Rubus allegheniensis Porter (Common blackberry)* [SS, GS—Native]
	Rubus flagellaris Willd. (Northern dewberry)* [SS, GS, P—Native]
Rutaceae	*Ptelea trifoliata* L. (Wafer-ash, hop-tree)* [SS, GS—Planted]
Salicaceae	*Populus deltoides* Marshall (Cottonwood)* [GS—Planted]
	Populus grandidentata Michx. (Large-tooth aspen, big-tooth aspen) [SS—Planted]
	Salix amygdaloides Andersson (Peach-leaved willow)* [W—Native]
	Salix cordata Michx. (Sand-dune willow, furry willow)* [GS—Planted]
	Salix exigua Nutt. (Sandbar willow)* [W, WS—Planted]
	Salix myricoides Muhl. (Blueleaf willow)* [W—Native]
	Salix x *pendulina* Wenderoth (Weeping willow)* [W—Adventive]
Scrophulariaceae	*Verbascum thaspus* L. (Mullein, flannel plant, common mullein) [GS, W—Adventive]
Solanaceae	*Physalis heterophylla* Nees (Clammy ground-cherry)* [SS, GS—Native]
	Solanum carolinense L. (Horse-nettle)* [SS, GS—Adventive]
Typhaceae	*Typha latifolia* L. (Common cat-tail, broad-leaved cat-tail)* [W, WS—Native]
Verbenaceae	*Verbena hastata* L. (Blue vervain)* [SS, W—Planted]
Vitaceae	*Vitis aestivalis* Michx. (Summer grape)* [SS—Native]
	Vitis labrusca L. (Fox grape)* [SS—Native]
	Vitis riparia Michx. (River-bank grape)* [SS—Planted]

*Voucher specimen(s) deposited in HLSD.
†Microhabitat abbreviations (SS = Steep slope; GS = Gentle slope; P = Prairie; W = Wetpanne; WS = Wetland shelf).
‡Status descriptions—"Planted" refers to being part of the original reclamation planting list. "Native" (native to Michigan) or "Adventive" (non-native) status refers to establishment at MPSM reclamation site.

TABLE 2. Numbers of planted, native and/or adventive species present‡, including species richness, in five microhabitats at the former Manley-Peters sand mine in Grand Mere State Park.

Microhabitat	Initial species planted	Planted species		Non-planted species		Species richness
		Still persisting	Additional colonizers†	Native	Adventive	
Steep slopes	36	15	4	21	9	49
Gentle slopes	25	11	9	18	15	53
Prairie	15	7	5	9	7	28
Wetpanne	41	25	4	20	7	56
Wetland shelf	14	5	4	9	0	18

‡"Planted" refers to being part of the Palmgren's (2004) original reclamation planting list. "Native" (native to Michigan) or "Adventive" (non-native) status refers to separate establishment from outside the MPSM reclamation site.
†Species from Palmgren's (2004) restoration plan that are present in the microhabitat, although not planted there initially. These taxa likely colonized from original plantings of adjacent microhabitats.

Some of the species from the planting list occupied more than one habitat, although only planted in one or two microhabitats (Tables 1, 2; Appendix I). For example, *Lycopus americanus* (common water horehound) was only planted in the wetpanne, yet it was also present on steep and gentle slopes, as well as in the prairie area (Table 1). The wetpanne had 25 out of 41, or 61%, of its original species present (Table 2), but 29 species overall, because four additional species from adjacent microhabitats have established there too (Tables 1, 2). The steep slopes had 19 planted taxa overall and the gentle slope had 20 species overall from the original list, while the prairie and wetland shelf had 12 and nine of the planted species present, respectively (Table 2).

Species richness for the site overall was 150, and as mentioned previously, some taxa were found in more than one microhabitat (Table 1). Of the microhabitats, the wetpanne had the highest species richness count at 56 taxa, followed by the gentle slopes with 53 taxa (Table 2). Fifty-eight species of Michigan's native flora have volunteered at the site, with native taxa being present in each microhabitat (Tables 1, 2). Twenty-seven adventive species were present across the MPSM reclamation site too, however, none were found among the wetland shelf flora (Tables 1, 2).

DISCUSSION

As of the 2011 growing season, almost 57% of the original reclamation planting list has been documented as part of the existing flora at the MPSM site (Tables 1, 2). The success of a reclamation effort can be difficult to quantify; nevertheless, MDNR originally stated that success would be evaluated based on continuing colonization of at least 60% of all planted species (Palmgren, 2004). Although our survey did not reveal 60% post-planting survival of the original plantings, we recognize the possibility that a few plants may have been overlooked, especially where vegetation was dense (as in the wetpanne) or submerged, and we did not sample the shallow water or deep water vegetation. One taxon, *Lobelia kalmii* (Kalm's lobelia), was part of the original planting list but then removed as it was difficult to propagate. In the revised plan, Palmgren (2004) reported that *L. kalmii* had established naturally by 2003, suggesting an indication of early progress of the restoration. We consider this restoration a success given that 58 species of native Michigan plants have also established at the site since the reclamation began (Table 1).

Emory and Rudgers (2010) performed an ecological assessment of 18 dune restorations in the Great Lakes region, including the MPSM site, and geographically paired, natural dune sites. We cannot directly compare our findings with those of Emory and Rudgers (2010), as data collection methodology and analyses differed, but they did report that the MPSM site had a higher species richness than that of its paired, natural site. It would be interesting to acquire the locality information of MPSM's natural counterpart in Grand Mere State Park, as determined by Emory and Rudgers (2010), so that species richness between the two

sites could be effectively compared using our microhabitat-delineated sampling method.

The presence of newly colonized flora and fauna suggest that the reclamation site has integrated with the surrounding dune areas of Grand Mere State Park. Several species of fauna, including bluegill, herons, sandhill cranes, and a red-tailed hawk, have been observed at the dune over the years (R. Cooper *et al.*, personal observation). Turkeys were present during several collections, and tracks and scat provided evidence of the regular presence of deer, as well. One of the objectives of the reclamation was to provide suitable habitat for both animals and plants native to the area, and our field observations support this. The wetpanne area had a species richness of 56, and over a third of the documented taxa were native volunteers (Table 2). Interdunal wetlands, or wetpannes, are ranked as imperiled in Michigan and globally (Palmgren, 2004) and thus, having such a rich flora in the MPSM wetpanne microhabitat is another measure of success for this thorough restoration effort.

Of the 27 adventive taxa documented at the MPSM site, *Bromus tectorum* was found on steep slopes, gentle slopes, the prairie area, and the wetpanne, while *Rumex acetosella* occurred in both slope habitats and the prairie (Tables 1, 2). At present, it might be appropriate to monitor these invasive species more closely to judge whether action is needed to remove them from the reclamation site. Most of the other adventive taxa were found in one or two microhabitats, but none were documented in the wetland shelf (Tables 1, 2).

In July 2012, a site visit was made to confirm identification of some of the MPSM flora for this publication. The water levels were quite low to the point of having submerged aquatics exposed in a terrestrial setting. *Iris virginica* (southern blue flag), part of the planting list outlined in the reclamation plan, was seen in 2004, but not again until the recent 2012 visit (R. Cooper and J. Van Zant, personal observation). It was present in a few places where the water levels were low, but not where documented previously in 2004. Hopefully, *I. virginica* will be confirmed as one of the post-planting survivors in future assessments.

Three of the 2011 surveys also included 1-m^2 quadrat sampling, according to methods described in Bonham (1989), and these took place across the seasons in May, June, and July. A "hybrid" version of quadrat and transect methodologies was used to ensure that each microhabitat was sampled according to the area each occupied at the site, and at least 38 quadrats were analyzed in each season. We do not show the data here for frequency and cover abundance, as only a subset of the total flora fell within the quadrat sampling areas. As might be expected, *A. breviligulata* had high frequency and cover-abundance values, as it occupies much of the slope habitats and was present in several of the quadrat samples (Saunders, 2012). We have the GPS coordinates recorded for each quadrat sample for use in further monitoring if deemed desirable by MDNR.

Human disturbance, in the form of litter and illegal fishing, is evident at the MPSM reclamation site (M. Edwards and R. Cooper, personal observation). A"Reclamation in Progress" sign, seemingly more effective during the early monitoring years, has since been removed. We propose that some signage be added to the gated area to warn against trespassing. Some level of supervision

may be warranted in the future, especially during busy holiday weekends in the spring and summer, to reduce human impacts on the restored site.

The baseline species richness observed in this study will be used in future monitoring every five years as recommended by MDNR (G. Palmgren, personal communication). Since planting methods differed among species (see Appendix I), an analysis of post-planting survival based on planting method would allow MDNR to better evaluate the value of each approach and, perhaps, modify further reclamation efforts. Future studies on bird, fish, insect, and/or mammal populations would also give a broader picture of the ecological viability of the site. In our opinion, MDNR has shown the "practicality of replanting a more diverse and natural vegetation cover which will complement the surrounding undisturbed vegetation" (Palmgren, 2004), and we appreciate being part of such sound ecological and conservation practices demonstrated at this innovatively reclaimed site in southwest Michigan's Grand Mere State Park.

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APPENDIX I. Restoration plan (adapted from Palmgren, 2004) for the former Manley-Peters sand mine in Grand Mere State Park.

Species (common name)	Microhabitat (estimated area) Planting method
Steep slopes (18.7 acres)	
Ammophila breviligulata (Beach grass, marram grass)	Plugs
Anemone canadensis (Canada anemone)	Seeds
Andropogon gerardii (Big bluestem, turkey foot)	Seeds
Aquilegia canadensis (Wild columbine)	Seeds
Arctostaphylos uva-ursi (Bearberry, kinnikinik)	Plugs
Artemisia campestris (Wild wormwood)	Plugs; seeds
Asclepias verticillata (Whorled milkweed)	Seeds
Calamovilfa longifolia (Sand reed grass)	Seeds
Campanula rotundifolia (Bluebell, harebell)	Seeds
Carpinus caroliniana (Hornbeam, blue-beech)	Seeds
Cornus sericea (Red-osier)	Plugs
Elymus canadensis (Canada wild rye)	Seeds
Euphorbia corollata (Flowering spurge)	Plugs
Hamamelis virginiana (Witch-hazel)	Plugs
Maianthemum stellatum (Starry false solomon-seal)	Plugs
Juniperus communis (Common juniper; ground juniper)	Plugs
Lathyrus japonicus (Beach pea)	Seeds
Monarda punctata (Dotted mint, horse mint)	Seeds
Panicum virgatum (Switch grass)	Seeds
Pinus strobus (White pine)	Bare-root trees
Populus grandidentata (Large-tooth aspen, big-tooth aspen)	Rooted cuttings
Prunus pumila (Sand cherry)	Plugs
Ptelea trifoliata (Wafer-ash, hop-tree)	Plugs
Quercus alba (White oak)	Bare-root trees
Quercus rubra (Red oak)	Bare-root trees/seedlings; acorns
Quercus velutina (Black oak)	Bare-root trees
Rudbeckia hirta (Black-eyed susan)	Plugs
Salix cordata (Sand-dune willow, furry willow)	Rooted cuttings
Schizachyrium scoparium (Little bluestem)	Seeds
Smilax rotundifolia (Common greenbrier)	Seeds
Solidago nemoralis (Gray goldenrod, old-field goldenrod)	Plugs
Sorghastrum nutaus (Indian grass)	Seeds
Symphyotriclium oolentangieuse (Sky-blue aster, prairie heart-leaved aster)	Plugs
Tradescantia ohiensis (Common spiderwort)	Plugs
Vernonia missurica (Missouri ironweed)	Seeds
Viburnum acerifolium (Maple-leaved viburnum)	Plugs
Vitis riparia (River-bank grape)	Plugs
Gentle slopes (4.3 acres)	
Amelanchier arborea (Juneberry)	Plugs
Arnoglossum atriplicifolium (Pale Indian plantain)	Plugs; seeds
Artemisia campestris (Wild wormwood)	Plugs
Calamovilfa longifolia (Sand reed grass)	Seeds
Carex pensylvanica (Sedge)	Transplants
Cornus florida (Flowering dogwood)	Plugs
Elymus canadensis (Canada wild rye)	Seeds
Hamamelis virginiana (Witch-hazel)	Plugs
Lindera benzoin (Spicebush)	Plugs
Liriodendron tulipifera (Tulip tree)	Plugs
Lupinus perennis (Wild lupine)	Seeds

(Continued)

APPENDIX I. Continued.

Species (common name)	Planting method
Microhabitat (estimated area)	
Gentle slopes (4.3 acres) (Continued)	
Opuntia humifusa (Prickly-pear)	Plugs
Panicum virgatum (Switch grass)	Seeds
Populus deltoides (Cottonwood)	Rooted cuttings
Prunus pumila (Sand cherry)	Plugs
Pteridium aquilinum (Bracken fern)	Transplants
Quercus alba (White oak)	Bare-root trees
Quercus rubra (Red oak)	Bare-root trees
Schizachyrium scoparium (Little bluestem)	Seeds
Smilax rotundifolia (Common greenbrier)	Plugs; seeds
Symphyotrichum pilosum (Frost aster, hairy aster)	Plugs
Tilia americana (Basswood, linden)	Plugs
Tradescantia ohiensis (Common spiderwort)	Plugs; quart pots
Vaccinium angustifolium (Low sweet blueberry)	Quart and gallon pots
Viburnum acerifolium (Maple-leaved viburnum)	Plugs
Prairie (1.3 acres)	
Calamovilfa longifolia (Sand reed grass)	Plugs
Coreopsis tripteris (Tall tickseed, tall coreopsis)	Chaff/seeds
Elymus canadensis (Canada wild rye)	Plugs
Koeleria macrantha (June grass)	Plugs
Lithospermum caroliniense (Hairy puccoon, yellow puccoon, plains puccoon)	Plugs
Lupinus perennis (Wild lupine)	Seeds
Monarda fistulosa (Wild-bergamot)	Seeds
Monarda punctata (Dotted mint, horse mint)	Seeds
Panicum virgatum (Switch grass)	Plugs
Rudbeckia hirta (Black-eyed susan)	Chaff/seeds
Schizachyrium scoparium (Little bluestem)	Plugs
Solidago nemoralis (Gray goldenrod, old-field goldenrod)	Seeds
Symphyotrichum ericoides (Heath aster, wreath aster, white prairie aster)	Seeds
Tradescantia ohiensis (Common spiderwort)	Plugs
Vernonia missurica (Missouri ironweed)	Plugs
Wetpanne (2 acres)	
Asclepias incarnata (Swamp milkweed)	Plugs
Bidens cernua (Nodding beggar-ticks)	Seeds
Calamagrostis canadensis (Blue-joint)	Plugs
Carex comosa (Sedge)	Plugs
Carex cryptolepis (Sedge)	Plugs
Carex flava (Sedge)	Plugs
Carex hystericina (Sedge)	Plugs
Carex lurida (Sedge)	Plugs
Carex stricta (Sedge)	Plugs
Carex suberecta (Sedge)	Plugs
Cirsium muticum (Swamp thistle)	Seeds
Cladium mariscoides (Twig-rush)	Plugs
Coreopsis tripteris (Tall tickseed, tall coreopsis)	Seeds
Eupatorium perfoliatum (Boneset)	Plugs
Euthamia graminifolia (Grass-leaved goldenrod)	Plugs
Hibiscus moscheutos (Swamp mallow, rose mallow)	Plugs
Hypericum kalmianum (Kalm's St. John's-wort)	Plugs
Iris virginica (Southern blue flag)	Plugs

(Continued)

APPENDIX I. Continued.

Species (common name)	Planting method
Microhabitat (estimated area)	
Wetpanne (2 acres) (Continued)	
Juncus acuminatus (Sharp-fruited rush)	Plugs
Juncus alpinoarticulatus (Rush)	Plugs
Juncus balticus (Rush)	Plugs
Juncus biflorus (Two-flowered rush)	Plugs
Juncus brachycephalus (Rush)	Plugs
Juncus effusus (Soft-stemmed rush)	Plugs
Juncus marginatus (Grass-leaved rush)	Plugs
Juncus torreyi (Torrey's rush)	Plugs
Lobelia cardinalis (Red lobelia, cardinal-flower)	Plugs
Lobelia siphilitica (Great blue lobelia)	Plugs
Lycopus americanus (Common water horehound)	Plugs; seeds
Peltandra virginica (Arrow-arum, tuckahoe)	Plugs
Pontederia cordata (Pickerel-weed)	Seedlings
Rudbeckia hirta (Black-eyed susan)	Plugs
Sabatia angularis (Rose-pink; rose gentian)	Seeds
Sagittaria latifolia (Wapato, duck-potato, common arrowhead)	Plugs
Schoenoplectus acutus (Hardstem bulrush)	Plugs
Schoenoplectus pungens (Threesquare)	Plugs
Schoenoplectus tabernaemontani (Softstem bulrush)	Seeds
Scirpus cyperinus (Wool-grass)	Plugs; seeds
Thelypteris palustris (Marsh fern)	Transplants
Verbena hastata (Blue vervain)	Plugs
Vernonia missurica (Missouri ironweed)	Plugs
Wetland shelf (3.2 acres)	
Alisma sp. (Water-plantain)	Plugs; tubers
Aronia prunifolia (Chokeberry)	Plugs; seeds
Calamagrostis canadensis (Blue-joint)	Plugs
Carex hystericina (Sedge)	Plugs
Carex lupulina (Sedge)	Seeds
Carex lurida (Sedge)	Plugs
Carex stricta (Sedge)	Plugs
Cephalanthus occidentalis (Buttonbush)	Plugs; seeds
Cladium mariscoides (Twig-rush)	Plugs
Cornus amomum (Pale dogwood, silky dogwood)	Plugs
Cornus sericea (Red-osier)	Plugs
Decodon verticillatus (Whorled loosestrife, swamp loosestrife)	Plugs
Ilex verticillata (Michigan holly, winterberry, black-alder)	Plugs
Iris virginica (Southern blue flag)	Plugs
Juncus balticus (Rush)	Plugs
Juncus effusus (Soft-stemmed rush)	Plugs
Lindera benzoin (Spicebush)	Plugs
Lobelia cardinalis (Red lobelia, cardinal-flower)	Plugs
Nuphar advena (Yellow pond-lily)	Tubers
Nymphaea odorata (Sweet-scented waterlily)	Tubers
Peltandra virginica (Arrow-arum, tuckahoe)	Plugs
Pontederia cordata (Pickerel-weed)	Plugs
Physocarpus opulifolius (Ninebark)	Seeds
Rosa palustris (Swamp rose)	Plugs
Sagittaria latifolia (Wapato, duck-potato, common arrowhead)	Plugs
Salix exigua (Sandbar willow)	Rooted cuttings

Continued

APPENDIX I. Continued.

Species (common name)	Planting method
Microhabitat (estimated area)	
Wetland shelf (3.2 acres) (Continued)	
Schoenoplectus pungens (Threesquare)	Plugs
Schoenoplectus tabernaemontani (Softstem bulrush)	Plugs
Scirpus atrovirens (Bulrush)	Plugs
Sparganium americanum (American bur-reed)	Seeds
Spiraea alba (Meadowsweet)	Plugs
Shallow water (1.9 acres)	
Brasenia schreberi (Water-shield)	Transplants
Nuphar advena (Yellow pond-lily)	Tubers
Nymphaea odorata (Sweet-scented waterlily)	Tubers
Potamogeton amplifolius (Large-leaved pondweed)	Transplants
Potamogeton gramineus (Pondweed)	Transplants
Potamogeton nodosus (Pondweed)	Transplants
Schoenoplectus tabernaemontani (Softstem bulrush)	Plugs
Scirpus cyperinus (Wool-grass)	Plugs
Deep water (3.9 acres)	
Potamogeton amplifolius (Large-leaved pondweed)	Transplants
Potamogeton gramineus (Pondweed)	Transplants
Potamogeton zosteriformis (Flat-stemmed pondweed)	Transplants
Stuckenia pectinata (Sago pondweed)	Transplants
Vallisneria americana (Tape-grass, wild-celery, eel-grass)	Transplants

THE SUGAR MAPLE SAPSTREAK FUNGUS (*CERATOCYSTIS VIRESCENS* (Davidson) MOREAU, ASCOMYCOTA) IN THE HURON MOUNTAINS, MARQUETTE COUNTY, MICHIGAN

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ABSTRACT

Sugar maple sapstreak disease is caused by the native fungus *Ceratocystis virescens* (Davidson) Moreau, but is only a serious threat in disturbed areas or where soil conditions favor the disease. Three of 16 trees along roads, in logged areas or other disturbance that showed crown symptoms of sugar maple sapstreak disease in the Huron Mountains were confirmed or probable for the disease based on xylem condition and laboratory isolation of the fungus. Trees diagnosed with the disease had greater than 50% crown dieback, while all trees free of the disease had lesser degrees of crown dieback. Although the presence of sugar maple sapstreak disease was confirmed in the Huron Mountains the incidence was found to be low. Results suggest this pathogen exists at low levels in the Huron Mountain forests and is not an imminent threat to sugar maple there. Soil conditions and other factors contributing to a generally healthy forest may be responsible for low incidence and spread of the disease.

KEYWORDS: sugar maple, sapstreak disease, Huron Mountains, *Ceratocystis virescens*, fungi

INTRODUCTION

Maple sapstreak is a disease of sugar maple trees (*Acer saccharum* Marsh.) throughout the eastern United States and Canada caused by the fungus *Ceratocystis virescens* (Davidson) Moreau (Houston and Fisher 1964, Houston 1993, Houston 1994). Previous names used for this fungus are *Endoconidophora virescens* and *C. coerulescens*; however, the latter species is now considered restricted to conifers (Witthuhn *et al.* 1998), while the former is the anamorph (asexual stage) of *C. virescens*. A current listing of species within the genus *Ceratocystis* includes 214 named taxa (CABI 2011). The taxonomic placement of *C. virescens* is as follows: **Family:** Ceratocystidaceae; **Order:** Microascales; **Class:** Sordariomycetes; **Phylum:** Ascomycota; **Kingdom:** Fungi (EPPO/CABI 2003).

Ceratocystis virescens is a xylem inhabitant of sugar maple, although it has been reported in several other woody species in living trees and on cut logs (Roth, *et al.* 1959, Shigo 1962). The fungus is considered among the most common fungi in northern hardwoods (Shigo 1962). Early reports of the occurrence of the fungus, however, must be taken with caution due to confusion in taxonomy and difficulty in identification. For example, a monograph of the genus

(Upadhyay 1981) does not separate *C. coerulescens* from *C. virescens*. These fungi do not decay wood *per se*, nor do they produce large fruiting bodies.

Ceratocystis virescens is a native fungus related to the pathogens that cause oak wilt (*C. fagacearum* (Bretz) Hunt, a native species), Dutch elm disease (*Ophiostoma ulmi* Buisman (formerly *C. ulmi*), an introduced species), and blue stain defect in conifer and hardwood lumber (several native species of *Ceratocystis* and/or their anamorphs). Native pathogens are generally present at low levels in all forest ecosystems. Although once considered a potential threat to sugar maple forests (Kessler 1978), sapstreak disease is rare in healthy stands of sugar maple but occurs mainly where trees are stressed typically by root compaction, logging or some other sort of human disturbance (Houston 1993, Houston 1994). Water-logged soils prone to rutting may also contribute to spread of the disease (Houston 1994).

The fungus infects trees through wounds, especially logging wounds, or damage along roads and in maple syrup operations (Hepting 1944, Mielke and Charette 1989, Houston 1993, 1994). It is suspected the disease is vectored by insects, however, little is known about its spread and the exact species of insects have not been identified (Kile 1993). It is likely that generalists such as sap beetles and fruit flies are involved in the spread of the disease. Symptoms of the disease include wilting, yellowing and dwarfing of leaves, and dieback of branches in the crown, leading to decline and eventual death of the tree, often within one to two years (Mielke and Charette 1989, Houston 1993, 1994). Further symptoms occur in the wood, where dark reddish-brown to blue-green streaking occurs (Figure 1); staining of wood is seen in wood at the base of the trunk in the root-flare region of the tree (Houston 1993). This symptom makes the disease identifiable in the field when bark from root flares is removed with a hatchet or chisel. In the laboratory, dark hyphae present in xylem vessel and parenchyma cells can be observed microscopically. The fungus can also reside in downed logs and stumps, and was isolated in 2008 in the Huron Mountains from a small, dead sugar maple tree along the road to Ives Lake (Richter 2008). In August 2010, a further examination of 16 suspect sugar maple trees and one stump bearing living sprouts was conducted to assess the incidence of sugar maple sapstreak disease in the Huron Mountains.

METHODS

The forests of the Huron Mountains in northern Marquette Co., Michigan are owned principally by the private Huron Mountain Club (approximately 20,000 acres (8,094 ha)), and are used for recreation, research and a small amount of forest management (Figure 2). The forests are a mixture of hemlock-northern hardwood, pine (red, white, jack) and wetlands (Simpson, *et al.* 1990). Small parcels within the Huron Mountains area are owned by private individuals for recreation homes. The other major landowner in the area is a commercial logging and real estate firm. Considerable logging operations are conducted on lands bordering the Huron Mountain Club lands.

Sixteen sugar maple trees with varying degrees of crown dieback or other indication of stress along roads or other forms of disturbance in the Huron Mountains were sampled Aug 20–22, 2010; fifteen were standing stressed and declining trees, and one was a recently fallen tree. Additionally, a stump of a tree cut three years before containing live wood and sprouts was also sampled. Table 1 gives the location, diameter, amount of crown dieback and xylem condition of the trees sampled.

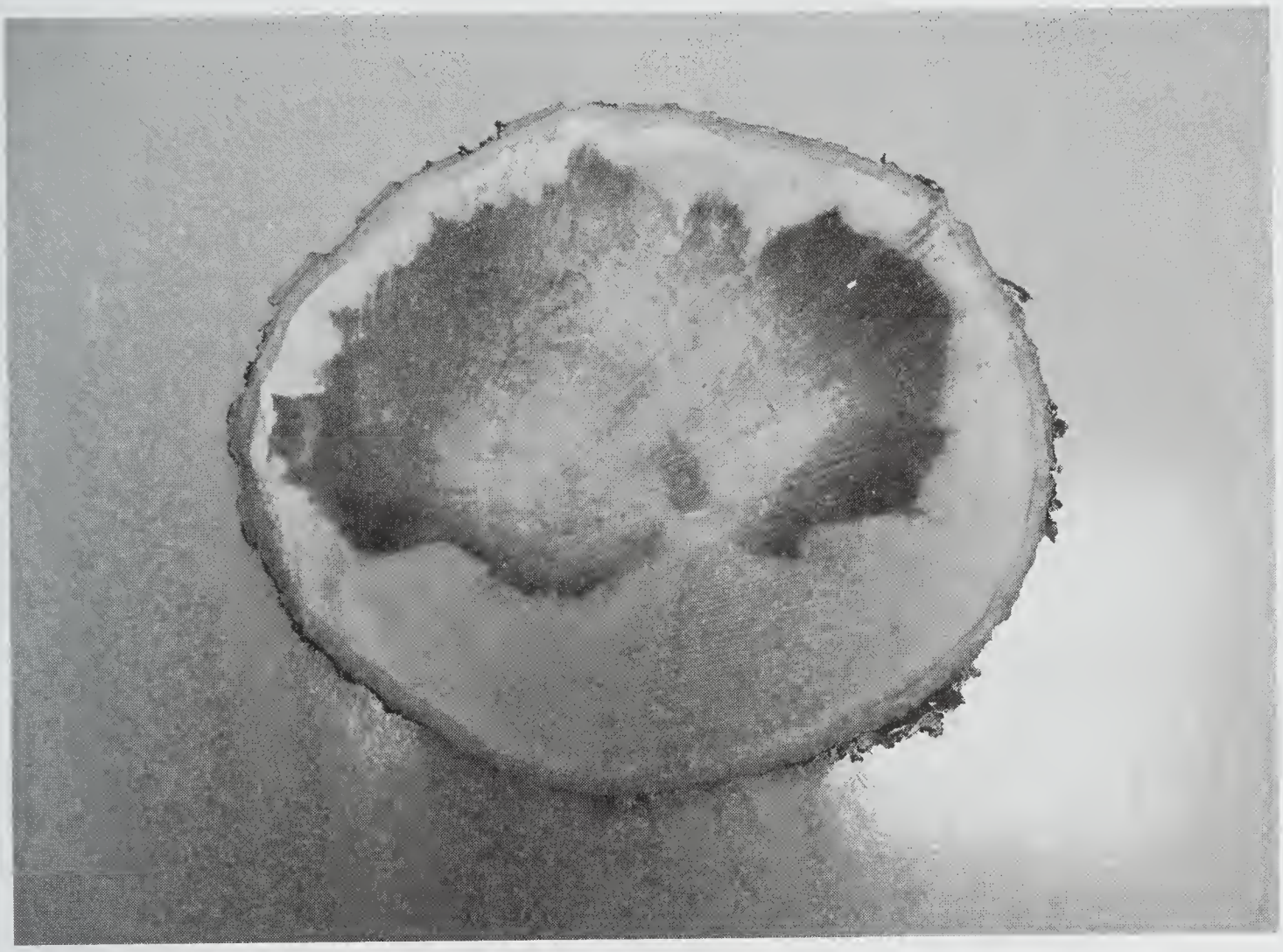

FIGURE 1. Thirty cm diameter section of a freshly cut sugar maple stem in Houghton Co., Michigan showing dark stain caused by infection by *Ceratocystis virescens*, the pathogen of sapstreak of maple.

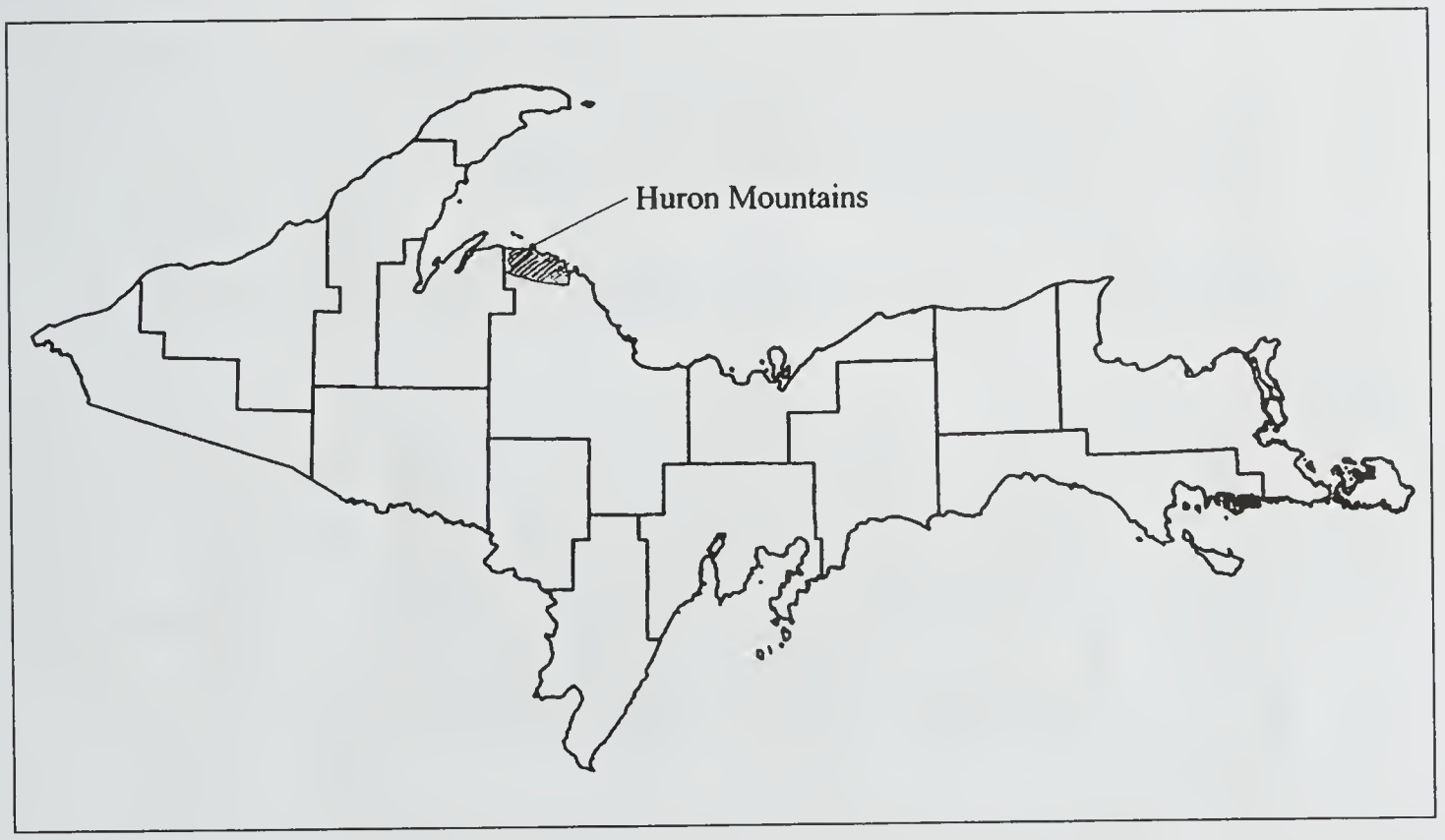

FIGURE 2. Location of the Huron Mountains in northern Marquette Co. in the Upper Peninsula of Michigan.

TABLE 1. Sugar maple trees sampled for sapstreak disease 20–22 Aug 2010 in the Huron Mountains; only trees with stained xylem indicating the possible presence of the sapstreak fungus were cultured in the laboratory.

Tree Number	Location	Section Number	Latitude Coordinate	Longitude Coordinate	Diameter Breast Height (cm)	Crown Dieback (%)	Xylem Condition	Laboratory Isolations	Presence of Sapstreak
1	Road to 3rd Pine Lake	34	N46.86243	W87.84636	30	25	no staining	—	No
2	Road near Lily Pond	2	N46.84750	W87.82563	45	10	no staining	—	No
3	Road near Lily Pond	2	N46.84750	W87.82563	60	25	no staining	—	No
4	Road to Ives Lake	2	N46.84750	W87.82563	20	25	no staining	—	No
5	Road to 3rd Pine Lake	34	N46.86385	W87.84192	30	50	no staining	—	No
6	Gravel pit near Skeet Field	17	N46.89821	W87.89211	60	80	dark streaking	*Trichoderma*	Probable
7	Gravel pit near Skeet Field	17	N46.89821	W87.89211	45	80	dark streaking	*C. virescens*	Confirmed
8	Gravel pit near Skeet Field	17	N46.89821	W87.89211	60	50	no staining	—	No
9	Gravel pit near Skeet Field	17	N46.89821	W87.89211	60	25	no staining	—	No
10	Road to Flat Rock	18	N46.90255	W87.92384	30	10	no staining	—	No
11	Road to Flat Rock	18	N46.90255	W87.92384	60	10	no staining	—	No
12*	Road to Flat Rock	18	N46.90255	W87.92384	30	—	dark streaking	Decay fungus	No
13	Road to Flat Rock	18	N46.90255	W87.92384	45	25	no staining	—	No
14	Road to Ives Lake	1	N46.85112	W87.81038	45	25	no staining	—	No
15	Road to Ives Lake	1	N46.85112	W87.81038	45	25	no staining	—	No
16	Road to Mountain Lake	29	N46.87588	W87.88191	90	10	no staining	—	No
17	Road to Mountain Lake	29	N46.87017	W87.89316	45	50	dark streaking	Decay fungi (2)	Probable

* #12 a stump cut three years previous with sprouts and living cambium.

Sampling consisted of removing 2–3 chips of xylem per tree with a hatchet directly under the bark of a root-flare at the base of a tree; chips were approximately 8 × 5 cm, and 1–2 cm thick.

Samples from four trees with dark streaking in the xylem characteristic of sapstreak disease were cultured in the laboratory. Isolations were made on 2% malt-agar in 60 mm Petri dishes; trunk samples were first surface sterilized with 10% chlorine bleach; per tree, nine pieces (approx. 2 × 2 × 0.3 mm) of stained inner xylem were excised using a sterile scalpel and placed in three Petri dishes (three pieces per plate). Plates were grown at 22–24°C for 7–10 days and examined for fungus growth. Fungus structures of *C. virescens* were examined at 400× with a Nikon Optiphot® microscope. At least ten fruiting structures and spores were measured to determine size range and confirm identity of *C. virescens* according to Davidson (1944).

RESULTS

The sugar maple trees sampled ranged in diameter from 20–90 in diameter; crown dieback ranged from 10–80%. Only four of the 17 trees sampled exhibited dark staining in the xylem characteristic of sugar maple sapstreak disease (Table 1). Of these four trees, two (#6 and #17) were determined to be probable infections based on color of xylem alone since *C. virescens* was not isolated; other fungi that were isolated likely out-competed *C. virescens* in culture, #6 by *Trichoderma* sp. (a mold fungus), and #17 by two decay fungi (unidentified). One tree (#7) was confirmed infected with the sapstreak fungus by laboratory isolation of *C. virescens*; and one tree (#12, stump with living wood and sprouts) was unlikely infected with sapstreak, the coloration in this case due to a dark decay fungus which was isolated instead (tentative identification, *Xylaria* sp.).

The culture of *C. virescens* obtained from sugar maple tree #7 (DR-492) was confirmed by examining growth on agar, hyphal characters, fruiting structures and spores, and compared to the description provided by Davidson (1944). Dark black mycelium covered the agar surface in a 90 mm petri plate in 10 days; the culture had a sweet, musty odor. Abundant fruiting bodies (perithecia) were produced which were approximately 0.6–0.8 mm upright in length, with bases 30–50 µm diameter and tips 12–15 µm diameter (Figure 3); ascospores collected at tip of asci were hyaline, slightly curved, 6–7 × 2 µm; conidiospores formed directly from hyphae were hyaline, cylindrical and highly variable in size approximately 6–25 × 3–6 µm.

The three trees probable and confirmed (#6, #7, #17) for sapstreak disease had from 50–80% crown dieback (Figure 4); two other trees with 50% crown dieback had clear xylem and no evidence of sapstreak; all other trees with less than 50% crown dieback also showed no evidence of sapstreak in the xylem. Two of the trees showing sapstreak disease (#6 probable, #7 confirmed) were on the edge of an excavation for gravel; the other probable sapstreak tree (#17) was along the road to Mountain Lake. Serious root damage caused by excavation or road compaction is the likely factor in these cases of sapstreak disease.

DISCUSSION

Although the presence of sapstreak disease of sugar maple was confirmed in the Huron Mountains, the incidence was found to be low, and relatively few trees

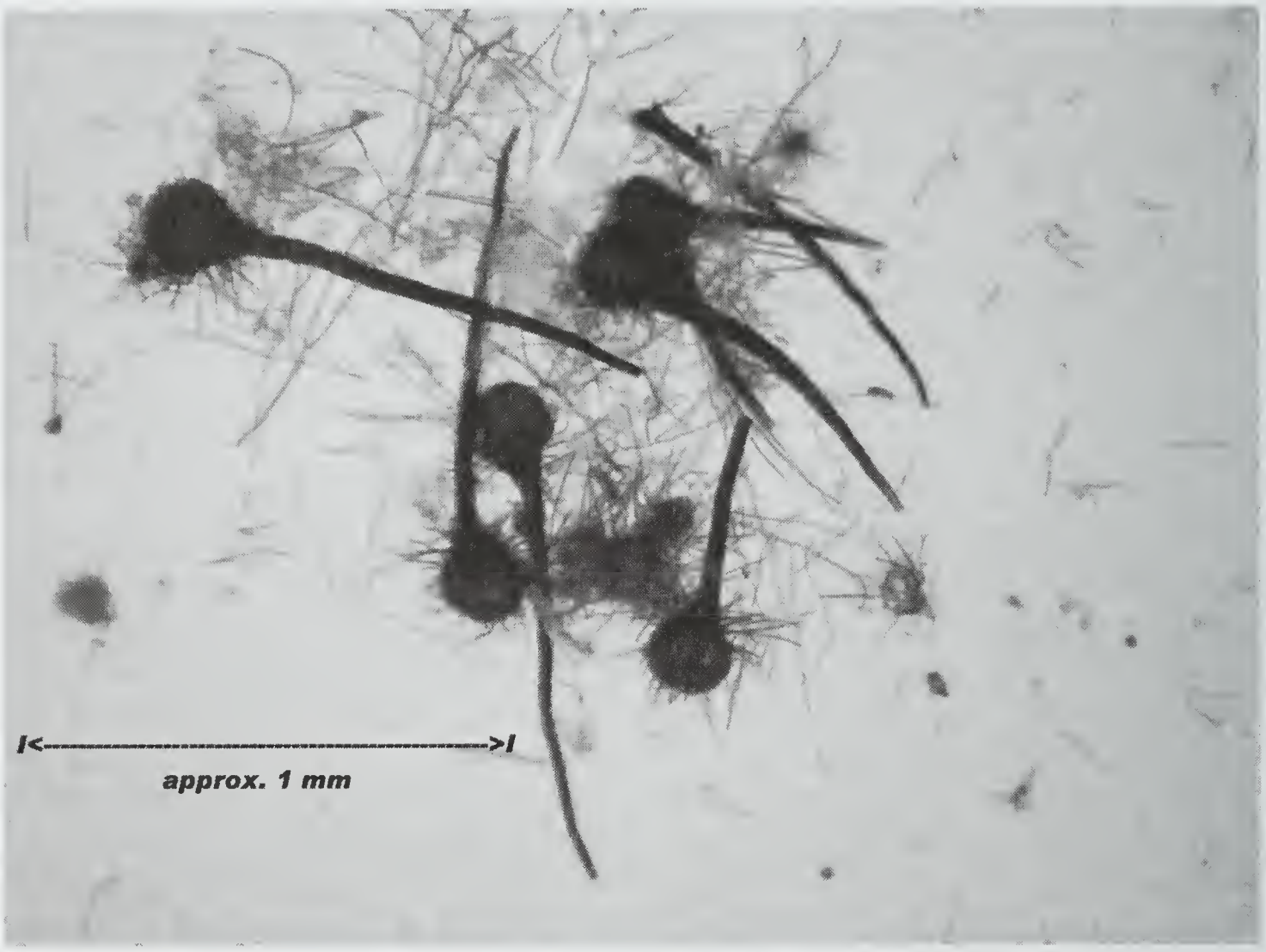

FIGURE 3. Ascocarps (perithecia) of the sugar maple sapstreak fungus *Ceratocystis virescens* (Davidson) Moreau; globose bases approx. 50 µm diameter; perithecial necks 0.6–0.8 mm long.

with symptoms of crown dieback were infected with *C. virescens* as indicated by xylem staining or laboratory isolation of the pathogen. The trees sampled do not represent the sugar maple forest as a whole in the Huron Mountains, but were selected based on having some form of disturbance and susceptibility to the disease. The disease was confirmed only in trees which had undergone major disturbance to the roots along a road and the edge of a gravel pit; these trees had 50-80% crown dieback. Results of the incidence of sapstreak disease may be different if wounded trees were exclusively sampled; however, the single tree sampled having a logging wound (#4) did not have stained xylem, while the stump with living tissue and stained xylem (#12) did not yield *C. virescens* by laboratory culture; staining in the latter was likely due to a dark-colored decay fungus.

Thirteen of the 16 stressed sugar maple trees in the Huron Mountains that exhibited 10–50% crown dieback, and one stump with living sprouts were apparently free from sapstreak disease; this implies that something other than sapstreak disease was affecting tree crown condition resulting in dieback. The cause of the dieback in these trees is likely physiological stress due to root compaction caused by roads and excavation. That these trees were not subsequently infected by the sapstreak fungus suggests that this native pathogen exists at low levels in the Huron Mountains. Factors contributing to a generally healthy forest may be responsible for the low incidence and spread of the disease. The low

FIGURE 4. Stressed sugar maple trees #6 and #7 on the edge of a gravel pit in the Huron Mountains with 80% crown dieback (center and right); these trees contained stained xylem, evidence of sap-streak disease; *Ceratocystis virescens* was isolated from tree on right. (Photo taken 21 Aug 2010)

incidence of the disease might also be due to the vast extent of old growth and the limited amount of logging that has been conducted in the forests of the Huron Mountains.

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NOTEWORTHY COLLECTION

MICHIGAN

Asplenium rhizophyllum L. Walking Fern.

Previous Knowledge. Asplenium rhizophyllum L. (synonym: *Camptosorus rhizophyllus* L.) is currently listed as a threatened species in Michigan (Penskar & Higman 1997) and has a global ranking of G5 S2/S3 indicating it is secure through most of its range but in some regions it is considered critically imperiled (Natureserve 2011). Limited habitat may account for its rarity in Michigan. *Asplenium rhizophyllum* is generally found on mossy boulders or outcrops composed of calcareous rocks, particularly limestone and dolomite, or rarely, on sandstone (Cobb, 2005). It is most abundant in the eastern Upper Peninsula on the dolomite and limestone outcrops of the Niagara Escarpment (Penskar & Higman, 1997). Seven Michigan counties have collection records: Alpena, Berrien, Chippewa, Delta, Dickinson, Mackinac and Leelanau (on Manitou Islands only, where it is found on mossy cedar logs in wooded dunes), (Michigan Flora Online 2011) but it has also been observed in Houghton Co. (Penskar & Higman, 1997). It is also found in the border county of Florence, Wisconsin, where it is given no special status (USDA 2011).

Significance of the Report. The colony was first observed in 2006, although no collection was made. This is the first collection for Alger County and the only collection from the Early Ordovician Au Train Formation, a light brown to white dolomitic sandstone (National Park Service, 2012). Though our meander survey of the area detected only two isolated colonies (Fig 1), more potential habitat exists. The localized occurrence of this species in Michigan creates unique challenges to the conservation of these vulnerable populations. It is important to document these occurrences in order to understand the full extent of the species range in Michigan as well as its ecological requirements.

Diagnostic Characters. Asplenium rhizophyllum roots from the tips of its arching fronds, hence its common name "walking fern" (Fig. 2). Another rare *Asplenium* in Michigan is *A.scolopendrium,* which is only known from Chippewa and Mackinac Counties. Both species occur in similar habitats and have entire fronds. Several distinctions can be made between these species. The most obvious field distinction is the tip rooting that occurs in *A.rhizphyllum*, but not *A.scolopendrium.* Also, in *A.rhizophyllum* the frond apex tapers into a gradual point whereas in *A. scolopendrium* the frond apex tapers abruptly to a point, or is more or less rounded (Michigan Flora, 2012).

Specimen citation. Alger Co. Michigan; Hiawatha National Forest. Two colonies of no more than one square meter in size were growing on sandstone boulders approximately four meters apart. The specimen was collected in a hardwood forest. Also growing on the boulders hosting *A.rhizophyllum* were *Dicentra americana* and *Sambucus racemosa.* Associated species in the immediate area included *Acer saccharum, Abies balsamea, Picea glauca, Tilia americana,*

FIGURE 1. Collection area and habitat of *A. rhizophyllum*. Photo taken by Lauren Tarr, 2012.

FIGURE 2. *Asplenium rhizophyllum*. Illustrated by Susan Fawcett.

Ostrya virginiana, Sambucus racemosa, Carex communis, Carex leptonervia, Oryzopsis aspirifolia, Allium tricoccum, Claytonia caroliniana, Dicentra sp., *Erythronium americanum, Galium* sp., *Hepatica americana, Maianthemum canadense, Osmorhiza* sp., *Taraxacum officinale, Trillium grandiflorum, Viola* sp., *Cystopteris fragilis*, *Dryopteris carthusiana, Polystichum lonchitis* and *Polypodium virginianum.* Specimens were collected by Susan Fawcett and Michael Rotter on April 12th 2012 and deposited at NM (Rotter 528). Duplicates were deposited at UM, and the Hiawatha National Forest. The collection was made under a Forest Products Free Use Permit from the US Department of Agriculture-Forest Service.

ACKNOWLEDGMENTS

We would like to thank Steve Caird and Lauren Tarr for field support. Thanks to Deb Le Blanc and Dr. Tony Reznicek for collection and permitting advice and Dr. John Anderton for information on the geology of the area.

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BOOK REVIEWS

Pringle, Peter. 2008. *The Murder of Nikolai Vavilov: The Story of Stalin's Persecution of One of the Great Scientists of the Twentieth Century*. New York. Simon & Schuster. 370 pp. ISBN-13: 978-0-7432-6498-3. $26.00. Hardbound.

In this captivating biography of the Russian plant geneticist/botanist Nikolai Vavilov, Pringle tells the story of how one of the twentieth centuries greatest botanists who dreamed of feeding the world died of starvation. Though he worked for numerous years for the Russian state, Vavilov was persecuted, incarcerated, interrogated and very likely tortured by Stalin's communist regime for his unwavering confidence in Mendelian genetics.

Vavilov, as portrayed by Pringle, was a passionate man full of energy, insatiable curiosity and unrelenting drive. He was first and foremost a scientist, though Pringle also devotes time to discussing Vavilov's family life. And though many of the charges brought against Vavilov by the KGB were of subterfuge and disloyalty to the motherland, Pringle works throughout the biography to show Vavilov as the incomparable patriot he is revealed to be in numerous personal journals, letters, interviews and records. Vavilov even tried to convince American contemporaries working at the time with T. H. Morgan to come to Russia and join him in his botanical cross breeding experiments. Of those who accepted Vavilov's invitation, only a few lived through the closing of Stalin's fist around scientists he deemed to be too theoretical.

Fueled in part by the common suspicion of the time that academics, particularly those well born, did not have the interests of the common people at heart, the U.S.S.R eventually stalled biological advancement in the motherland by fully backing the work of the uneducated would-be scientist, Forim Lysenko. Ironically, Vavilov played a key part in the recognition of Lysenko's work on vernalization. For many years, Lysenko worked on one of Vavilov's experimental breeding stations. Throughout Lysenko's career, Vavilov repeatedly extended the inexperienced Lysenko invitations to join him at international conferences on genetics and worked to give him opportunities to expand his knowledge base and improve as a scientist. However, Lysenko preferred a Lamarckian theory of genetics and would not be moved, a preference ultimately shared by Stalin himself. It is not surprising, therefore, after the forth of multiple famines hit Russia throughout the early 1900's, Stalin turned to Lysenko instead of Vavilov for a plan to rapidly improve Russian agriculture. Interestingly, the famines were caused in part by environmental factors, but greatly exacerbated by Stalin's grain collectivization program.

Lysenko, a formidable opportunist, worked at every turn to amass his own power and undermine Vavilov's own position. Pringle discusses Vavilov's reluctance to engage Lysenko in open conflict and confront his erroneous theory of inheritance and bad science. By the time Vavilov grasped the gravity of the situation, it was too late. It is interesting that a man so perceptive with plants was so blind to the darker side of people. Even throughout the times of persecution, Pringle paints a picture of a painfully optimistic Vavilov. He constantly wrote encouragement to his experimental institutes around Russia, maintained contact with his international colleagues and believed that the truth of science would triumph. None-the-less, Pringle writes, a different truth eventually dawned on the horizon: Vavilov would be arrested. In an address to his workers at the Leningrad Institute, he stated, "We will go into the pyre, we shall burn, but we shall not retreat from our convictions." Ar-

rested August 6, 1940 on the fictitious charges of sabotage of Soviet Agriculture and spying for foreign countries, particularly Britain, Vavilov was brutally interrogated. Initially sentenced to be shot on July 9, 1941, his sentence was later commuted to twenty years in labor camps. Neither sentence carried; Vavilov was found dead on January 26, 1943. The jail doctors pronounced the cause of death to be dystrophy from prolonged malnutrition.

Despite his unnecessarily early death, Vavilov made phenomenal advances in Russian agriculture. He worked tirelessly to keep himself and his workers abreast of and contributing to international agrarian developments. On each of his multiple and varied excursions to locate "hot spots" of plant biodiversity and species origins, He would bring back fruits, vegetables, and hoards of seeds and grains common to other continents but not yet seen in Russia. Each specimen was saved in his ever-expanding seed library and many were directly used in agricultural experiments at field stations throughout Russia. His now famous and nearly globally inclusive collection of seeds, arguably one the first gene seed banks in the world, even managed to survive World War II. Pringle writes of workers in the Institute of Leningrad starving to death in their desks as they maintained vigil over the collection. Vavilov, as Pringle reveals, was indeed a man of contagious vision.

In constantly searching for new varieties of existing crops, he dreamed of "directing the evolution of cultivated plants and domestic animals according to our will," seeing his mission as one for all humanity. Although the director of multiple institutes over the span of his life, Vavilov never sought administrative promotion, preferring instead to be in the laboratory or the field performing genetic experiments on his preciously obtained varieties. None-the-less, his formidable education from the Petrovskaya Agricultural Institute, post-graduate studies and internships in Russia, Britain, France and Germany, and publically recognizable genius at one point landed him eighteen administrative posts. He served a decade as the director of the Institute of Genetics of the Academy of Sciences of the USSR, during which time period he also functioned as the vice president of the 6th International Congress of Genetics in Ithaca, New York. In the time since Vavilov's death, Russia has recanted. Vavilov was rehabilitated in 1955. Thirty-three years later the country celebrated the centenary of his birth. Russian citizens today proudly recognize Vavilov as one of their foremost scientists. The Russian Government posthumously granted Vavilov an honorary doctorate and presented it to his second son, Yuri, on November 27, 2007 at a special symposium honoring the 120th anniversary of Vavilov's birth at the Russian State Agrarian University in Moscow.

As Pringle mentions, it is starkly ironic that a man who dreamt of feeding the world would die of starvation. One cannot help but wonder how the world would be different had Vavilov lived. He carried out specimen collecting tours of extensive breadth on five continents to better understand and hopefully harness the genetic variability globally present in wild and cultivated plants. Over his lifetime, Vavilov created a botanical library of over 250,000 specimens and published prolifically. Yet even today, his dream of feeding the world remains unrealized.

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Quammen, D. 2008. *On the Origin of Species: The Illustrated Edition.* Sterling Publishing Company, 387 Park Avenue South, New York, NY 100016, 544 pages. ISBN 1402756399 $35.00.

Charles Darwin is arguably the most well known scientist who has ever lived. The views he developed on his fateful trip around the world would change the face of biology for-

ever. He spent years after his voyage collecting evidence until he was forced to publish his findings more than 23 years after his return. His book, titled *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* was in instant success and was followed by many further editions.

The interest in Darwin and his work continues to this day. Many who are interested in biology have read at least part of *The Origin of Species*. However, this edition is different than many. In contrast to the many small paperback versions available, this edition is large (9×10 inches) and hardbound with a nicely illustrated dust jacket. The resulting decrease in portability is more than made up for by the beautiful illustrations on almost every page. They portray the diversity Darwin saw, the species he observed and snapshots of his life. Some of the illustrations were made on the voyage of the Beagle, while others are from Darwin's later publication *The Zoology of the Voyage of H.M.S. Beagle.* In addition to the illustrations, many related snippets were included from Darwin's voyage diary as well as other publications on his life. Although the text was taken directly from Darwin's *Origin of Species,* the liberal sprinkling of additional text and pictures greatly enhances the reading experience.

Anyone interested in biology will find this book fascinating, whether you have previously read *The Origin of Species* or not. The illustrations and glimpses into Darwin's life add further depth and meaning to his exploration of natural selection and the processes of change. This book would be an excellent addition to any biological library.

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Theodoropoulos, D. I. 2003. *Invasion Biology: A Critique of a Pseudoscience*. Avvar Books, Blythe, CA 92225. 236 pp. ISBN 0-9708504-1-7, paperback $14.50.

Our increasing awareness of just how dramatically humans can alter ecological systems has spawned new subdisciplines of biology. I doubt that any of us today would, if given a second chance, exterminate the passenger pigeon (*Ectopistes migratorius*): the idea of conservation biology is too prominent in our minds. We wish to preserve the ecosystems we observe around us. Invasion biology has sprung from that same mindset: we've seen the damage we inflict when we transport species from a distant geographic locality and introduce them to our native flora and fauna. Examples in our area include the house sparrow (*Passer domesticus*), brought from Europe and now competing with our beloved eastern bluebirds (*Sialia sialis*), reedgrass (*Phragmites australis* subsp. *australis*) originally from Europe and now abundant in our marshes, and the zebra mussel (*Dreissena polymorpha*), which has become extremely prevalent in the Great Lakes.

But David Theodoropoulos has a different idea. In his controversial book *Invasion Biology*, he argues that "invasive species" are actually not a threat to native wildlife; instead of being harmful, "alien" species typically integrate quickly into their new ecosystem, induce natives to evolve more quickly, and increase diversity in the areas into which they spread.

The first section, which is roughly half of the book, deals with the science behind this issue. In rapid-fire succession Theodoropoulos cites many examples of species which invasion biologists claim are demonstrably harmful to native wildlife, but which he claims are completely innocuous. "Non-natives" aren't the problem, he says; anthropogenic destruction of ecosystems is—and in fact, non-natives typically show up in areas disturbed

by humans. Dispersal of exotics is nothing to be afraid of, he reiterates—it happens naturally all the time.

Theodoropoulos devotes the second half of his book to a discussion of the psychology of invasion biology. He does not stop at refuting the scientific claims of "anti-alien" scientists: invasion biology is a pseudoscience, he says, and appears to be born of some basic human xenophobia. In quick succession the author lists several analogous principles or behaviors in both invasion biology and Nazism. Theodoropoulos attributes paranoia, propaganda, a money connection with pesticide companies, and a hateful attitude towards anything "foreign" to invasion biologists.

In the last and smallest section of *Invasion Biology* the author brings his arguments to a conclusion, and directs the reader to what he thinks is the real crisis: bias against "alien" species will hamper our ability to protect the planet's biodiversity. If a particular plant is rare, feel free to cultivate it in your backyard or greenhouse! says Theodoropoulos. By keeping as much diversity as possible spread throughout the planet, species are much less likely to go completely extinct. He cites several examples where the only members of a species left in existence are in a zoological park or cultivation—*Gladiolus citrinus*, *Franklinia alatahama*, and *Tecophilia cyanocrocus* for example. There are no theoretical limits to diversity, he argues, so we should try to pack as many species as possible in appropriate environments; it doesn't matter whether they are "native" or "alien". Furthermore, the language we use to describe exotics—aggressive, invasive, alien, biological pollution—should be changed in order to eliminate bias and reflect a new understanding of the role of "non-natives". Anthropogenic dispersal is a critical duty not to be neglected, not a matter for unscientific fear or regulation by bureaucracy.

This reviewer feels that Theodoropoulos' argument would have been much better made and received had he simply omitted the second section of his book, and left that can of worms to open at a later date if he so desired. I am not convinced that yanking the garlic mustard (*Alliaria petiolata*) from my woods is tantamount to Ku Klux Klan activities. That said, I found this book to be highly intriguing. Theodoropoulos raises questions worthy of our attention: What exactly does "invasive" mean? How exactly does anthropogenic disturbance affect ecosystems? Are there some pros to having certain exotic species around? Have we overreacted and invoked too much red tape? Are the recent studies indicating that zebra mussels may actually be improving water quality of our Great Lakes correct? Will the house sparrows disappear and leave the bluebirds to live their lives, if the agricultural disturbance ceases? How exactly do we carry out our role as stewards on this solitarily verdant planet?

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On the cover: Opuntia humifusa *(Prickly-pear) from the gentle slope microhabitat at the former Manley-Peters sand mine in Berrien County's Grand Mere State Park. (Photograph by Ranessa L. Cooper on 24 June 2008.)*

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HYBRIDIZATION DYNAMICS OF INVASIVE CATTAIL (*TYPHACEAE*) STANDS AT PIERCE CEDAR CREEK INSTITUTE: A MOLECULAR ANALYSIS

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ABSTRACT

Three cattail taxa are recognized in Michigan USA: native *Typha latifolia* (broad-leaf cattail), the invasive *Typha angustifolia* (narrow-leaf cattail), and the hybrid of these two species *Typha* × *glauca*. *Typha angustifolia* and *T.* × *glauca* are of special interest because of their ability to aggressively spread and out-compete the native cattail *T. latifolia*. *Typha* × *glauca* has been shown to out-compete both its parental taxa and produce monospecific stands. We surveyed the Pierce Cedar Creek Institute (PCCI) property for cattails and located 25 distinct cattail marshes. We determined the total area of cattail marsh at PCCI to be roughly 10% of the 267 ha property. Cattail individuals were sampled from each of the 25 stands and RAPD markers were used to identify the individuals to species. We found that 20 of the 25 stands were monospecific for the native cattail, *T. latifolia*. Five of the stands were mixtures of the native *T. latifolia* and the introduced *T. angustifolia*, and *T.* × *glauca* was found in two of the mixed stands. We recommend removal of the invasive *T. angustifolia* and *T.* × *glauca* individuals and the establishment of a monitoring plan in order to maintain the long-term health of the cattail marshes at PCCI.

KEYWORDS: *Typha* spp., RAPD markers, invasive species

INTRODUCTION

Species of *Typha* L. (Typhaceae), commonly known as cattails, are highly productive emergent plants that grow in a variety of wetland habitats throughout the world (McManus et al. 2002). In the northern USA and Canada three taxa of cattail have been recognized: *Typha latifolia* L. (broad-leaf cattail), *Typha angustifolia* L. (narrow-leaf cattail), and *Typha* × *glauca* Godr. (white cattail). *Typha latifolia* is a native plant species that is a keystone emergent in marsh communities throughout North America (Smith 2000). In the United States, broad-leaf cattail is native to all 50 states. In Canada, it occurs in all provinces and territories except Nunavut (USDA, NRCS 2012).

Typha angustifolia is thought to have been introduced to the eastern seaboard from Europe in the early 19th century (Stucky and Salamon 1987; Selbo and Snow 2004), although Shih and Finkelstein (2008) suggest it may be present in pollen cores dating back 1,000 years. Following its colonization of the Atlantic coast, *T. angustifolia* began to move inland slowly—but by the early 20th century it had begun a rapid westward expansion (Mills et al. 1993). Today, *T. angusti-*

folia is found in 42 of the 50 United States; it is absent from Florida, Georgia, Alabama, Mississippi, Texas, Utah, Arizona, Hawaii and Alaska. In Canada it is found in all provinces except Labrador and Newfoundland and is absent in the Yukon, Northwest, and Nunavut Territories (USDA, NRCS 2012). Because of its aggressive spread, *T. angustifolia* is considered an invasive species. It often outcompetes native wetland species, including *T. latifolia*, to produce very dense monospecific stands (Grace and Harrison 1986).

Typha latifolia and *T. angustifolia* are obligate wetland species, meaning that they are always found in or near water. Both species generally grow in flooded areas; however, *T. latifolia* is typically found in waters that do not exceed 0.8 m while *T. angustifolia* prefers deeper water, usually greater than 0.75 m. Where the two species are sympatric, they typically segregate by water depth (Travis et al. 2010).

According to Grace and Harrison (1986), both *T. latifolia* and *T. angustifolia* are self-compatible, wind pollinated, clonal species. The reproductive shoots of both species are monoecious, with staminate flowers occurring above pistillate flowers, and protogynous (pistillate flowers produced prior to staminate flowers). The pistillate flowers remain receptive to pollen for four weeks (Kuehn et al. 1999). While the protogynous condition would seem to facilitate out crossing (Smith 2000), Krattinger (1975) showed that cattails are largely self-fertilized and that vegetative reproduction occurs more frequently than sexual reproduction. In part, the two species can be distinguished by the presence or absence of a spike gap between the staminate and pistillate flowers (*T. latifolia* generally has no spike gap, whereas *T. angustifolia* has a spike gap ranging from 0.5 to 4 cm). *T. latifolia* often flowers later than *T. angustifolia* but overlap in flowering times can lead to hybridization between the species (Selbo and Snow 2004). In fact, *T. latifolia* and *T. angustifolia* appear to hybridize wherever the two occur sympatrically (Galatowitsch 1999; Kuehn et al. 1999; Olsen et al. 2009).

The third taxon, *Typha* × *glauca*, is the hybrid of *T. angustifolia* (maternal) and *T. latifolia* (paternal) (Grace and Harrison 1986; Kuehn et al. 1999); however, its hybrid status has long been disputed. *Typha* × *glauca* has been identified as a distinct species; a stabilized hybrid taxon; an introgressed taxon with *T.* × *glauca* representing a series of intermediates in a hybrid swarm; and also as a sterile F_1 hybrid (Kuehn et al. 1999 and references therein). Taxonomic descriptions of *T.* × *glauca* frequently identify the plant as a sterile F_1 hybrid; however, recent studies have revealed the presence of backcrossed and later generation hybrids indicating that *T.* × *glauca* has at least some degree of fertility (Snow et al. 2010; Kirk et al. 2011).

The spread of invasive taxa are of particular interest to evolutionary biologists and ecologists because of their ability to alter community structure and ecosystem function (Horvitz et al. 1998). *Typha* × *glauca* is considered to be a highly invasive species due to its aggressive range expansion and ability to dominate wetland habitats. According to Galatowitsch et al. (1999), several hypotheses have been advanced in an effort to explain how introduced plant species become invasive species. The Introgression/Hybrid Speciation hypothesis suggests that interspecific hybridization between an introduced taxon and a native taxon results in novel phenotypes with selective advantages. Therefore, hybridization

between native and introduced species is considered to be one of the driving forces behind the evolution of invasiveness (Ellstrand and Schierenbeck 2000; Schierenbeck and Ellstrand 2009). Hybrids between native and introduced species have frequently been shown to have increased fitness with respect to their parental species as they possess greater genetic and phenotypic diversity than their parents (Kuehn et al. 1999; Ellstrand and Schierenbeck 2006; Kirk et al. 2011). This appears to be the case for *T.* × *glauca* which can colonize the entire range of water depths in which the parental species segregate (Travis et al. 2010). Several researchers (e.g., Zedler and Kercher 2004; Travis et al. 2010) have documented the competitive superiority of *T.* × *glauca* indicating its potential as a highly invasive taxon.

F_1 hybrids are generally expected to be morphologically intermediate to their parental taxa but this is not necessarily the case for the hybrid *T.* × *glauca*. The leaf width of the hybrid *T.* × *glauca* is believed to range from 6 mm to 16 mm; although leaf widths up to 21 mm have been reported. Kuehn et al. (1999) found considerable phenotypic variation in leaf width for each of the parental species. The leaf width of *T. angustifolia* ranged from 4.5 mm to 12 mm and the leaf width of *T. latifolia* ranged from 7.5 mm to 22 mm. Therefore, the leaf width of *T.* × *glauca* overlaps with the parental species making this trait unreliable for hybrid identification. Flowering in cattails is also an unreliable trait for taxonomic identification because cattails often exhibit poor flower production. Dickerman (1982) found that over a three-year period only three of 1,779 marked shoots flowered at Lawrence Lake in Barry County, Michigan. The degree of shading, including self-shading in dense stands (Grace and Wetzel 1982), and the depth of rhizome submergence (Grace 1989) affect flowering success. In addition to poor flowering and the overlap in morphological traits, backcrossed and advanced generation hybrids are phenotypically more similar to one of the parental taxa further complicating the identification of hybrid individuals through morphological traits (Kuehn et al. 1999; Selbo and Snow 2004; Snow et al. 2010). Because morphological traits can be highly variable, DNA markers are considered to be more reliable for the identification of cattail species and their hybrids (Kuehn et al. 1999; Selbo and Snow 2004).

This study examined 25 discrete marsh populations at Pierce Cedar Creek Institute in Hastings, Michigan, USA in order to gain an understanding of the distribution and abundance of *T. latifolia, T. angustifolia*, and *T.* × *glauca*. We used random amplified polymorphic DNA (RAPD) markers coupled with intensive field sampling of the 25 populations to identify individual cattails to species. Kuehn et al. (1999) developed species-specific RAPD markers for *T. latifolia* and *T. angustifolia.* RAPD analysis of genomic DNA is expected to produce species-specific RAPD banding patterns while the hybrid, *T.* × *glauca*, is expected to display the banding patterns of each parent. Because of the potential for *T. angustifolia* and *T.* × *glauca* to invade the marsh communities at PCCI and out-compete the native *T. latifolia*, baseline data on the presence and distribution of *Typha* spp. is imperative to the development of an effective wetland management plan for the institute.

FIGURE 1. Cattail stands identified at Pierce Cedar Creek Institute in Hastings, Michigan. Numbers correspond with the coding assigned to sampled individuals. (See Table 1 for the species composition of each stand.)

METHODS

Study Site

This research took place at Pierce Cedar Creek Institute (PCCI) in Hastings, Michigan, USA. PCCI is an environmental field station and nature center whose property consists of forest, field, open water, and a variety of wetland habitats. Of the 267 ha site, a total of 103 ha is considered wetland. Brewster Lake and approximately 1.9 km of Cedar Creek are contained on the property and many of the wetlands are associated with these bodies of water. Most of the property was previously farmed and many of the wetland habitats along Cedar Creek appear to be recovering from disturbance. In addition, the creek has also been dammed by beavers. This has led to flooding and the creation of shallow water habitat which is ideal for cattail growth. The cattail composition at PCCI has not been previously studied, but a 2003 vascular plant inventory of the property indicated that only *T. latifolia* was present (Slaughter and Skean 2003).

Mapping of Cattail Stands

In April of 2012, we visually surveyed the property by traveling on foot along the trails, and also by canoeing Cedar Creek. After visual determination of the locations of cattail stands, each stand was mapped using a hand-held GPS unit (Garmin *e*-Trex 30). Mapping consisted of traveling the perimeter of each cattail stand with the GPS unit creating an electronic track file. This data was entered into a geographical information system (ArcGIS 10) to create a digital map depicting the location of each cattail stand on PCCI property (Fig. 1). Each track on the GPS, with the exception of the Brewster Lake track, was created by walking the perimeter of the cattail stand. The Brewster Lake track was created by rowing around the perimeter of the lake in a boat.

Taxon Sampling

Typha samples were collected from each identified cattail stand. Within each stand, we began collecting at the edge and traveled straight-line transects, by foot, through the stand, stopping at least every 10 m to collect leaf tissue from the nearest ramet (an individual shoot of a clonal organism). In larger stands, the distance between sampled ramets often exceeded 10 m. For stands that were too small to establish transects, or in cases where traveling in a straight line was impractical, sampled ramets were separated by a distance of no less than 10 m. Having a minimum distance of 10 m between samples has been shown to decrease the likelihood of sampling clone mates (Kuehn et al. 1999; Olsen et al. 2009; Snow et al. 2010). No *a priori* species assignments were made at the time of collection since *T. latifolia, T. angustifolia* and *T.* × *glauca* display significant overlap in leaf width (Kuehn et al. 1999, Olsen et al. 2009) and all samples were collected prior to flowering; however we did sample from a representative range of morphological variants within each stand. We sampled by clipping approximately 7 cm of leaf tissue from the youngest leaf. The tissue was immediately placed into a plastic bag containing silica gel desiccant. Each sampled ramet was flagged and numbered along with the corresponding tissue sample.

Molecular Identification of Typha Species and Hybrids

Total genomic DNA was extracted from approximately 3 cm^2 of dried leaf tissue following a variation of the 2 × CTAB (cetyl trimethylammonium bromide) extraction method for high polysaccharide plants described by Nickrent (2006). DNA extractions were stored at –20°C for use in genetic identification of species and hybrids.

We used RAPD molecular markers to identify *T. latifolia, T. angustifolia,* and *T.* × *glauca.* Total genomic DNA was amplified with PCR using RAPD primers A2 (TGCCGAGCTG) and A8 (GTGACGTAGG) (Eurofins mwg/Operon Huntsville, AL, USA). Each 25 µL reaction mixture contained 19.7 µL ultra-sterile H_2O, 2.5 µL 1 × PCR buffer (200 mM Tris-HCl [pH 8.4], 500 mM KCl), 1 µL 50 mM $MgCl_2$, 1 µL of either RAPD - A2 or RAPD - A8 primer, 0.25 µL 10 mM PCR Nucleotide Mix (USB Corp. Cleveland, OH, USA), 0.05 µL Platinum® Taq DNA Polymerase (Invitrogen, Carlsbad, CA, USA), and 0.5 µL total genomic DNA.

The 25 µL reaction mixtures were incubated in an iCycler Thermal Cycler (Bio-Rad Laboratories, Inc., Hercules, CA, USA) programmed for 2 min at 94°C (initial denaturation); 25 cycles of 1 min at 94°C, 1 min 30 sec at 34.5°C, and 2 min 20 sec at 72°C followed by 20 cycles of 1 min at 94°C, 1 min 30 sec at 34.5°C, and 2 min 20 sec at 72°C with a 10 sec increase after each cycle.

RAPD products were separated by gel electrophoresis on 1.2% agarose gels for 1 h at 90 V. Gels were stained in an ethidium bromide bath for 15 min and photographed under a UV light source. Molecular weights of amplification products were estimated using a 1 kb plus DNA ladder (Invitrogen, Carlsbad, CA, USA). Primer A2 yields 5 species-specific bands with bands for *T. latifolia* at 1.5 kb, 1.0 kb, and 0.6 kb and bands for *T. angustifolia* at 1.2 kb and 0.8 kb; primer A8 produces 3 species-specific bands with *T. latifolia* having a band at 1.0 kb and *T. angustifolia* having bands at 2.0 kb and 1.8 kb (Kuehn 1999). F_1 *T.* × *glauca* individuals are expected to show all parental bands.

RESULTS

Twenty-five wetland communities containing *Typha* spp. were identified from PCCI property (267 ha). These ranged in individual area from 8 m^2 to 97,613 m^2 (Table 1; Fig. 1). The largest stands were associated with the perime-

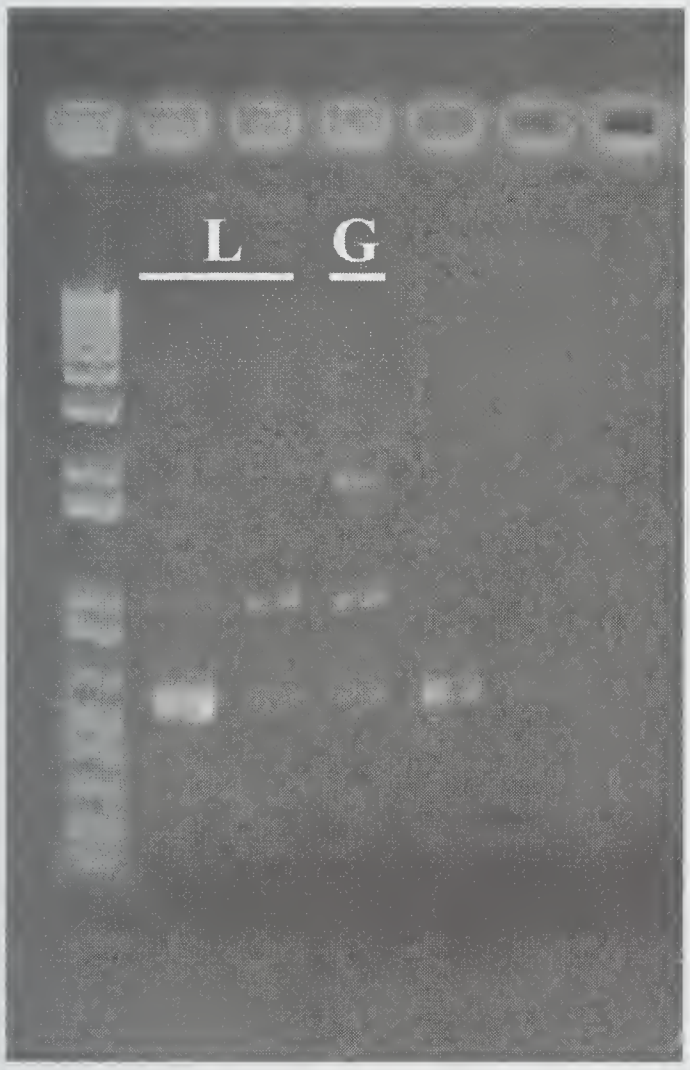
TABLE 1. Area, number of *Typha* individuals (n) identified, and species composition of the 25 cattail stands identified at Pierce Cedar Creek Institute. Area was calculated in Garmin *e-Trex* 30. The species composition of each stand (L - *Typha latifolia*, A - *Typha angustifolia*, and G - *Typha* × *glauca*) is presented as a percentage of each species per the total number of identified individuals from the stand.

Stand	Area (m^2)	n	% Species Composition
100	12181.00	9	L (100%)
200	717.82	4	L (100%)
300	27583.00	12	L (100%)
400	20048.00	15	L (100%)
500	3507.20	4	L (100%)
600	10751.00	8	L (75%), A (25%)
700	752.56	2	L (50%), A (50%)
800	22149.00	16	L (100%)
900	4607.00	16	L (100%)
1000	882.16	4	L (100%)
1200	97613.00	43	L (100%)
1300	14698.00	2	L (100%)
1400	14028.00	13	L (100%)
1500	5260.00	5	L (100%)
1600	3215.8.	8	L (100%)
1700S	207.03	3	L (33%), A (33%), G (33%)
1700N	177.02	3	L (100%)
1800	586.29	3	L (100%)
1900	95.06	1	L (100%)
2000	7133.76	8	L (100%)
2100	7695.90	14	L (77%), A (23%)
2200	2102.80	5	L (40%), A (20%), G (40%)
2300	1781.10	5	L (100%)
2400	371.96	3	L (66%), A (33%)
2500	1725.80	5	L (100%)
2600	7.63	1	L (100%)

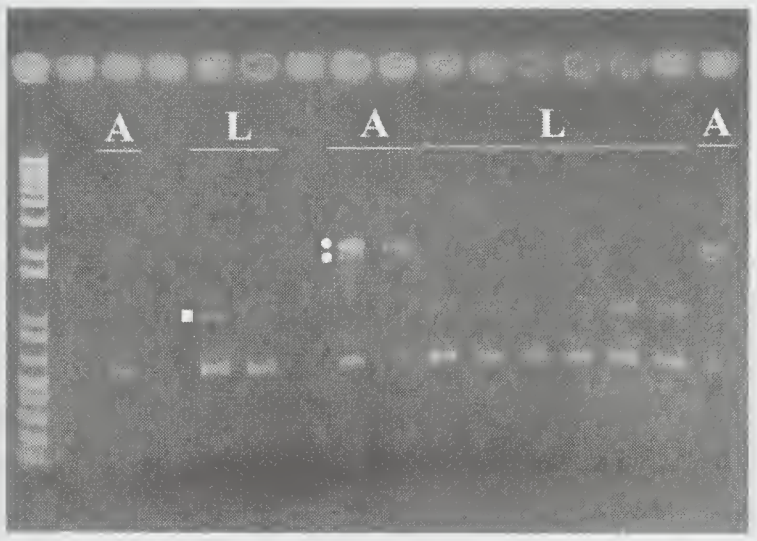
ter of Brewster Lake and the wetland complexes adjoining Cedar Creek. The smallest stand was a drainage ditch adjacent to the main road into the PCCI property. This road was constructed between 1999 and 2001 (Brown, Pers. Comm.). The cumulative area of all cattail stands totaled 259,878 m^2 (26.0 ha) which is approximately 9.72% of the PCCI property.

We collected tissue samples from a total of 370 individuals from across the 25 cattail stands. Of these, DNA was extracted from 252 randomly chosen individuals, representing all 25 stands. Photos of two representative electrophoresis gels of RAPD DNA fragments produced by PCR amplification of cattail individuals using primer A8 are shown in Figure 2. The species-specific bands and species identification are indicated on the photos. We identified most individuals to species using primer A8. For approximately 1% of the individuals we confirmed the primer A8 species identification using Primer A2. No difference in species identification was observed between the two primers. RAPD analysis allowed us to identify 212 of these individuals to species: 200 (94.34%) were *T. latifolia*, 9 (4.25%) *T. angustifolia*, and 3 (1.42%) were the hybrid *T.* × *glauca*.

Of the 25 cattail stands at PCCI, 20 were monospecific, consisting of only the



A.



B.

Figure 2. Two exemplary gel photos showing random amplified polymorphic DNA (RAPD) phenotypes for cattail individuals identified using primer A8. The left lane contains a 1-kb plus DNA ladder size standard. A species-specific band for *Typha latifolia* (■) occurs at 1kb and two species-specific bands for *T. angustifolia* (•) occur at 2.0kb and 1.8kb. A. One *T.* × *glauca* (G) and two *T. latifolia* (L) individuals identified by RAPD analysis. B. Eight *T. latifolia* (L) and four *T. angustifolia* (A) individuals identified by RAPD analysis.

native cattail, *T. latifolia*, four were mixed for *T. latifolia* and *T. angustifolia*, and two stands consisted of a mixture of both parental species and their hybrid *T.* × *glauca* (Table 1).

DISCUSSION

This study documents the extent to which the native cattail *Typha latifolia*, the introduced and widespread cattail *T. angustifolia*, and the hybrid of these two species, *T.* × *glauca* occur at Pierce Cedar Creek Institute. Approximately 40% of the PCCI property is characterized as wetland habitat based on its soil type and hydrology (Brown, pers. comm.). However, many of these wetlands are visibly dry throughout much of the year. Because cattails prefer standing water, we were surprised to find that nearly 10% of the property consisted of cattail marshes. The density and species composition within each sampled wetland varied from what appeared to be a monospecific stand of cattails with one ramet immediately adjacent to another, to stands in which individual cattail ramets were separated by distances of approximately 10 m. Diversity appeared to be much higher in these stands with a variety of sedges, forbs, and shrubs occurring in between the *Typha* ramets.

On our initial observation most stands appeared to be the native *T. latifolia* because the individual ramets consisted of broad leaves; however, variation in

leaf width led us to suspect that genotyping would reveal mixed stands of both parental species and their hybrid. Within the large stand that surrounded Brewster Lake (stand 1200; Fig. 1) a 50 m × 3 m patch of narrow-leaved ramets grew out into the lake to a water depth of about 1 meter. A second patch of narrow-leaved ramets occurred in stand 2100 in an area of deeper water. We suspected that individuals from these two patches of narrow-leaved, deeper water ramets would genotype to *T. angustifolia*.

Our results demonstrate that the native cattail, *T. latifolia,* is the dominant cattail species at PCCI; 20 of 25 cattail stands were monospecific for *T. latifolia*. Based on variation in leaf widths we believed that many of the cattails stands at PCCI would be mixed for both parental species and their hybrid. We found evidence of the widespread, introduced species, *T. angustifolia*, in only six of the 25 stands and in two of these mixed stands the hybrid *T.* × *glauca* was present. We had suspected that a patch of narrow-leaved individuals from the Brewster Lake stand (stand 1200; Fig. 1) was *T. angustifolia* but genotyping did not reveal any *T. angustfolia* individuals from Brewster Lake. This is likely due to random sampling of our collected tissue samples for genotyping which may have excluded individuals from this patch. Genotyping did however reveal the patch of narrow-leaved individuals from stand 2100 to be *T. angustifolia*. It should be noted that for most individuals we only analyzed a single RAPD locus and with only a single analyzed locus it is possible that individuals identified as *T. latifolia* could in fact be *T. angustifolia* if introgression has occurred. Therefore, there is a chance that our species assignments could be more complex if introgression is rampant throughout the cattail stands at PCCI. Additionally, our % species composition (Table 1) was calculated as a percentage of each species per the total number of RAPD identified individuals per stand. Since several stands had limited RAPD genotyping the % species composition should be considered tentative with regard to the entire stand.

The homogenous *T. latifolia* stands were primarily associated with the wetlands surrounding Brewster Lake and Cedar Creek. It is likely that these stands experience lesser disturbance from changes in hydrology and water depth. *Typha latifolia* is reported to have superior growth and competitive ability over *T. angustifolia* in shallow, undisturbed, water habitats (Grace and Wetzel (1989). By contrast, *T. angustifolia* was shown to be competitively superior to *T. latifolia* in shallow water habitats when they were highly eutrophic (Weisner 1993). We found that mixed parental stands were located in areas that are likely experiencing greater disturbance because of their proximity to the PCCI trail system, roads, and other anthropogenic influences such as culverts which may be acting to alter hydrology and increase sedimentation. Stand 1700S was of particular interest because it is a small retention pond that was constructed on the PCCI property sometime between 1999 and 2001 (Brown, Pers. Comm.). The very nature of a retention pond suggests fluctuating water levels and sedimentation. Since the hybrid *T.* × *glauca* can exist throughout the range of water depths occupied by its parental species it is not surprising that we identified a hybrid individual from this site.

It is well documented that when the native *T. latifolia* occurs sympatrically with the introduced *T. angustifolia* they can produce the hybrid *T.* × *glauca*

(Galatowitsch 1999; Kuehn et al. 1999; Olsen et al. 2009). *Typha angustifolia* itself can out-compete the native cattail, *T. latifolia*, and the hybrid *T.* × *glauca* can out-compete both parental species (Grace and Harrison 1986). Because the 2003 survey of vascular plants at PCCI (Slaughter and Skean 2003) did not identify the occurrence of *T. angustifolia*, we believe it has moved onto the property within the last ten years. Since a large patch of *T. angustifolia* is directly adjacent to the trail system (stand 2100) it is unlikely that the species was overlooked in the 2003 survey. Therefore, the presence of *T. angustifolia* is cause for concern regarding the long-term health of the native *T. latifolia* cattail marshes at PCCI. While the identification of hybrid individuals based on morphological characters alone is not reliable, the leaf width and spike-gap differences between the parental species seem to allow for the accurate identification of *T. angustifolia* in the field. We recommend the removal of all *Typha angustifolia* individuals and identified hybrids from the PCCI property in order to ensure the long-term health of the *T. latifolia* cattail marshes. The removal of *T. angustifolia*, the maternal parent of the hybrid, should prevent the formation of additional hybrid individuals on the PCCI property. At the very least, we recommend that PCCI undertake a monitoring program to record the health of, and/or changes to, the cattail marshes on their property.

A cattail marsh monitoring program should keep track of fluctuations in hydrology and water levels, as well as, the numbers and locations of the invasive cattail species. *Typha angustifolia* has been shown to prefer deeper water than *T. latifolia* (Travis et al. 2010). Therefore, if water levels increase around Brewster Lake or Cedar Creek, such as might be caused by beaver dams, the disturbance could create *T. angustifolia* appropriate habitat. Additionally, if a cattail marsh regularly receives additional water and nutrients from runoff, such as through the existing culvert systems, they are likely to experience increased growth of the invasive cattail species. An appropriate control technique would be to manipulate water levels so that the preferred *T. angustifolia* habitat is not available for colonization.

Optimally, all non-native cattail species would be removed from the PCCI property. According to the USDA NRCS Plant Guide (USDA, NRCS 2012) cattails can be removed by mowing the plants after the flowering heads are well-formed but before they have reached sexual maturity. This mowing treatment should be followed by a second mowing after 0.5 m–1 m (2–3 feet) of new growth has occurred (typically 1 month). This treatment opens up habitat for other emergent vegetation and has been shown to be about 75% effective in eliminating undesirable cattail stands. Additionally, herbicides can be applied to the rooted portion of the cut ramets which should kill the submerged rhizome and prevent regrowth. We predict that without intervention, *T. angustifolia* and *T.* × *glauca* will spread through the marsh complexes at PCCI altering their species composition and the foraging behavior of many of the animal species dependent on them.

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RELIC OR RECRUIT? NEWLY DISCOVERED *ARONIA ARBUTIFOLIA* (ELL.) PERS. (RED CHOKEBERRY) IN KENT COUNTY RAISES QUESTIONS REGARDING PAST AND FUTURE DISTRIBUTIONS

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ABSTRACT

The nomenclatural history of the genus *Aronia* is replete with name changes, misidentifications, and debates regarding classification. In Michigan, collections of *Aronia arbutifolia* (Ell.) Pers. (Red chokeberry) from the early 20th century are thought to be misidentifications of *Aronia prunifolia* (Marsh.) Rehder (Purple chokeberry). A recent discovery of *A. arbutifolia* in West Michigan could represent a rare species that has naturally occurred in Michigan in the past or an adventive individual that has only recently arrived. We provide documentation of the new state record and discuss its discovery in the context of earlier ambiguous records of Red chokeberry in the Great Lakes region. We also consider whether this species is exhibiting a coastal plain disjunct distribution, and we examine the possibility that Red chokeberry is expanding its range in response to climate change. Future genetic research and molecular analysis could help answer some of the questions raised by this interesting discovery in Michigan.

KEYWORDS: Red chokeberry; *Aronia arbutifolia,* coastal plain disjunct, climate change

INTRODUCTION

In 1933, at the annual meeting of the Torrey Botanical Society, renowned botanist and landscape architect Henry Teuscher (1933) gave an address on the question "*what is a species*?" In his short talk, he used the *Aronia* (chokeberry) complex to illustrate some of the inherent problems of using morphological criteria to define species of plants. Four decades later, Professor James Hardin (1973) revisited "the enigmatic chokeberries" in a paper that outlined the taxonomic and nomenclatural confusion surrounding the shrubs since the early 20th century. Today, the taxonomy of the two (or three) polymorphic chokeberry species in the *Aronia* genus (or sub-genus) is still debated, its history likely clouded by interbreeding (Hardin 1973; Voss 1985; Voss and Reznicek 2012), different reproductive strategies (Campbell et al. 1991; Hovmolm 2004), and inter-population variability (Hardin 1973; Uttal 1984; Brand 2010). Over the years, several different genus names have been assigned to this small group, including *Mespillus* L., *Pyrus* L. f., *Crataegus* Lam., *Adenorachis* Nieuwl., and *Photinia* K.R. Robertson & J.B. Phipps (MacMillin 1892; Nieuwland 1915; Britton and Brown 1970) [In this paper, we follow the nomenclature outlined by Voss (1985)]. More recently, studies involving nucleotide sequencing have established molecular phylogenies of *Pyrinae* (*Rosaceae*) that distinguish *Aronia*

from *Photinia* (Campbell et al. 2007; Potter et al. 2007; Guo 2011). Campbell et al. (2007) recommend maintaining *Photinia* and *Aronia* as separate genera, as their results yielded no molecular evidence for placing them together, "or even near one another," on a phylogenetic tree.

The state of Michigan is no stranger to the botanical confusion associated with these shrubs. Early plant surveys in the state, circa 1900, reported *Aronia arbutifolia* (Ell.) Pers. (Red chokeberry) in St Clair (Dodge 1900), Berrien (Beal 1904; Hebert 1934), Ionia (Beal 1904), Kent (Cole 1901), and other counties. Botanical literature from that period, e.g., W. J. Beal's *Michigan Flora* (1904), lists two species of *Aronia, A. arbutifolia* and *A. melanocarpa* (Michx.) Elliot. (Black chokeberry) [the latter actually listed as *A. nigra* in Beal (1904)]. However, these early records of Red chokeberry in Michigan are universally interpreted as either reports or misidentifications of *A. prunifolia* (Marsh.) Rehder (Purple chokeberry) (which sometimes appeared in older literature as a variety of *A. arbutifolia*). This taxon (*A. prunifolia)* is typically understood to have originated as a hybrid between *A. melanocarpa* and *A. arbutifolia* (Farwell 1918; Hardin 1973; Voss 1985). Our recent finding of *A. arbutifolia* in Kent County clarifies the occurrence of *Aronia* in Michigan by providing the first confirmed report of this taxon in the state. In this paper, we describe the *A. arbutifolia* discovery and then investigate some possible scenarios to explain its presence in West Michigan.

MATERIALS AND METHODS

On November 4, 2011, a group of eight potentially clonal Red chokeberries was discovered during a field trip to Townsend Park, Kent County, MI. The shrubs were found in a moist bottomland east of Bear Creek, growing in a backwater corridor that ran along the bottom of a west-facing hillside. A small grove of large *Thuja occidentalis* (Northern White cedar) (10–18″ dbh) filled the canopy around the chokeberries, affording a relatively open understory characterized by groundwater upwelling and several waste deep pockets of muck. To the west, a shrub zone of *Cornus spp.* (Dogwood), *Betula pumila* (Bog birch), *Zanthoxylum americanum* (Prickly ash), and *Physocarpus opulifolius* (Ninebark) transitioned into an open wet meadow dominated by *Carex stricta* (Tussock sedge), *Onoclea sensibilis* (Sensitive fern), and *Cirsium muticum* (Swamp thistle). A shrubby riparian zone marked the western edge of the meadow, the eastern banks of Bear Creek.

At the time of the discovery in early November, dozens of bright-red cymose infructescences populated the distal ends of the shrubs' branches. Tomentose beneath, the scarlet-colored leaves were elliptical and had short acuminate tips (Figure 1). The tallest shrub reached six meters in height and was supported by a cedar trunk. All the shrubs were elongate, their lower reaches mostly unbranched. Collections of flowering material were made on May 8 2012.

VOUCHER SPECIMENS:

Michigan, Kent Co., Cannon Twp. Townsend Park, c. 200 m SE of Ramsdell Dr. and Six Mile Rd., 43° 03′N, 85° 27′ W, 4 Nov. 2011, *M.P. Ryskamp 1* (CALVIN, MICH); *M.P. Ryskamp 2* (CALVIN, NY); 8 May 2012, *M.P. Ryskamp 5* (CALVIN, MICH).

RESULTS AND DISCUSSION

The presence of Red chokeberry in Kent County raises a variety of questions with regard to the origin, establishment, and mechanism of dispersal to West

FIGURE 1. Photograph taken November 4, 2011 at Townsend Park in Kent County, Michigan showing the tomentose leaves and hairy stems of *Aronia arbutifolia,* with canescent berries still attached.

Michigan. Below, we explore several different possibilities that might account for this surprising discovery, we discuss some of the implications of these possibilities, and we propose some future research initiatives.

Given the history of misidentifications of Red chokeberry in Michigan (and in other states), one possible explanation is that what we have identified as *Aronia arbutifolia* is actually an introgressant of the hybrid '*A. prunifolia* complex' (Uttal 1984). This possibility, however, can be eliminated due to several distinct morphological features of the Townsend Park chokeberries. Firstly, the red-colored fruits observed on the shrubs at the time of discovery are unique to *A. arbutifolia,* the fruits of *A. prunifolia* having a much darker purple to purple-black hue when ripe (Gleason and Cronquist 1963; Hardin 1973; Voss 1985). Uttal (1984) calls fruit color "the only reliable basis for separating chokeberry species." The fact that both leaves and berries remained on the shrub in November is also indicative of *A. arbutifolia;* both Purple and Black chokeberry produce fruit that ripen and drop earlier in the season (Hardin 1973; Voss 1985; Brand 2010). Additionally, the size of the pomes, which we measured to range 4–7 mm in diameter, is congruent with descriptions of *A. arbutifolia*—the pomes of *A. prunifolia,* in contrast, range from 8 to 10 mm (Gleason 1958; Gleason and Cronquist 1963). Lastly, Robinson and Fernald (1908) describe Red chokeberry as having cymes that are "more numerously fruited (9–18)" than those of *A. prunifolia*, which have 3–10 fruits. Even as late as November, the Townsend Park shrubs had some cymes with 10 or more pomes still attached (Figure 2), and during a field trip in May 2012, with the shrubs in full bloom, we counted 10–16 florets per cyme (Figure 3). In light of all these traits [and with confirma-

FIGURE 2. Another photograph taken on November 4, 2011 showing the bright red fall foliage and pomes of *Aronia arbutifolia*.

tion from A.A. Reznicek (personal observation)], we are confident that the shrubs in question are indeed *A. arbutifolia.*

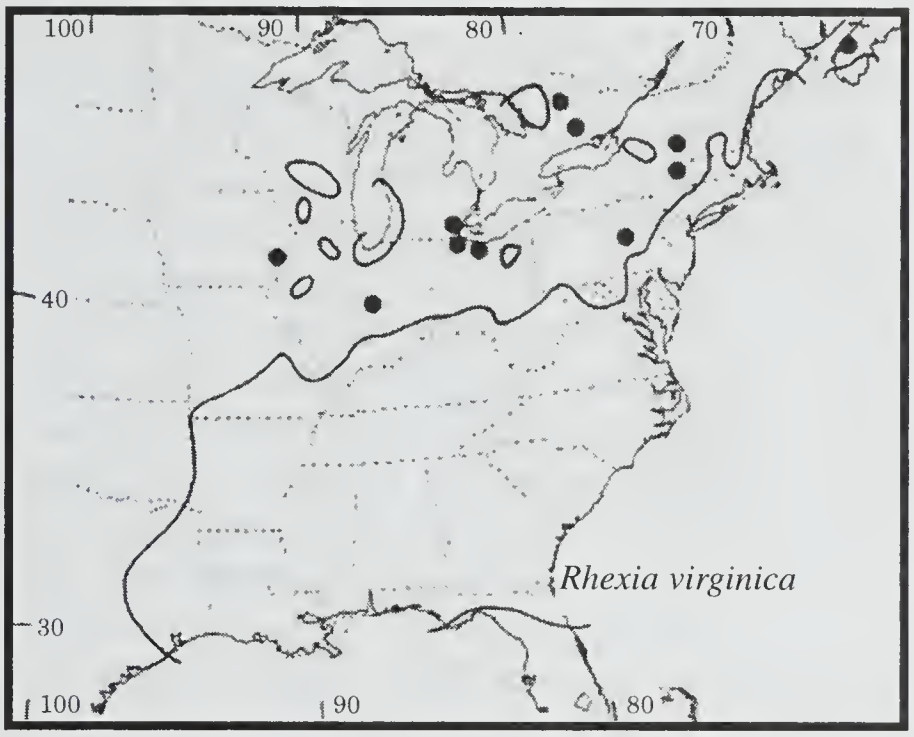
A second possible explanation for the presence of these shrubs is that they represent an escaped horticultural form. Again, we think this possibility is unlikely in light of how closely the shrubs match morphological descriptions of wildtype *Aronia arbutifolia* (as described in the above paragraphs). The most commonly sold cultivar (and perhaps the only one), *A. arbutifolia* 'Brilliantissima,' has a more compact form, more lustrous leaves, and has larger, glossier fruits than the wildtype species (Flint 1997; Dirr 2011). This description significantly contrasts with the small canescent berries and the tall elongate growth habit of the Townsend Park shrubs. Additionally, the habitat immediately surrounding the Townsend Park chokeberries was replete with native species that indicate relatively pristine conditions, which differs from the typical disturbed habitat in which most non-native escapees are found (Herman et al. 2001).

Though we are confident the Townsend Park shrubs are wildtype *Aronia arbutifolia,* there still remain several questions regarding *how, when,* and *from where* this species arrived. Distribution patterns of coastal plain species may provide important insight to these questions. There are several communities of disjunct flora around the Great Lakes region that occur outside their primary range of the Atlantic and Gulf coastal plains (Reznicek 1994). These concentrations

FIGURE 3. *Aronia arbutifolia* in full bloom, Townsend Park, Kent County, Michigan, May 8, 2012.

occur in three main areas: 1) a post-glacial drainage occupying southwest Michigan and northwest Indiana; 2) the region in Ontario east of the Georgian Bay; and 3) the sand deposits of central and northern Wisconsin. Smaller representations are scattered around the Great Lakes region, in northern Michigan and in a few different locations along the shores of Lake Erie and Lake Ontario. One of the most widespread of the disjunct species, *Rhexia virginica* (Meadow Beauty) occurs in all three main regions and in some of the minor areas from the western shore of Lake Erie eastward toward the St. Lawrence River (Figure 4a). The range of *A. arbutifolia* is similar to *Rhexia* (Figure 4b); it centers on the southeastern coastal plain, extending west along the Gulf coast into eastern Texas (Hardin 1973) and northward into the coastal areas of New England and into the southern portion of Nova Scotia (Eaton et al. 2010; Haines 2011). With *A. arbutifolia* identified in Kent County, it seems reasonable to ask if the same (or some of the same) edaphic and dispersal factors responsible for the presence of disjunct species around the Great Lakes are also responsible for bringing *A. arbutifolia* to Michigan—however recent or long ago that may have been.

Purported records of *Aronia arbutifolia* in Ontario (Accessed through GBIF Data Portal, data.gbif.org, 2012-01-21) would seem to support a coastal plain



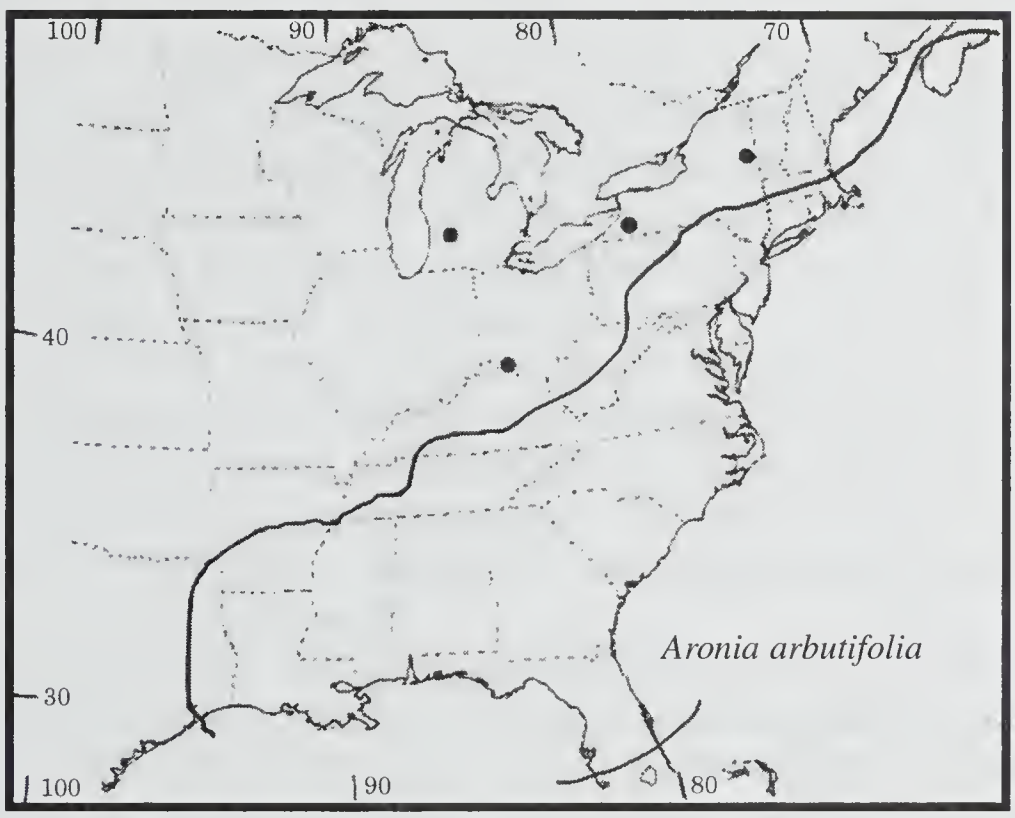


FIGURE 4. Distributions of *Rhexia virginica* (4a) and *Aronia arbutifolia* (4b). The original distribution map of *Rhexia* appears in Reznicek (1994); images used with permission from the author. The distribution of *A. arbutifolia* (4b) was based on Hardin (1973), Gardner et al. (2005), Haines (2011), and on selected records from the New York State Museum (available upon request).

disjunct distribution pattern, but these records have never been confirmed, and neither Shrubs of Ontario (Soper and Hiemburger 1982) nor the Ontario Plant List (Newmaster et al. 1998) recognizes *A. arbutifolia* as a component of Ontario's flora. Voucher specimens (collected in late summer and early fall) referenced in The New York Flora Atlas do show populations of Red chokeberries in the western region of the state, near Lake Ontario and Lake Erie, isolated from the main population along the Atlantic Coast. Further from the Great Lakes, in Nova Scotia, Red chokeberry is considered a member of the community of disjunct coastal flora that occurs in the southern region of that province (Eaton et al.

2010), where *Rhexia virginica* and several other disjunct species occur. Although some records remain dubious, it does appear that *A. arbutifolia* has a tendency to initiate disjunct populations outside its coastal plain range.

Reznicek (1994) hypothesizes that birds or possibly other dispersal agents played a role in shaping and sustaining populations of disjunct species. He adds that migrations of flora from the coastal plains into post-glacial drainages near the Great Lakes could have provided a seed source for dispersal agents. This may describe the causative events behind the establishment of *Aronia arbutifolia* in Kent County—dispersed by migrating birds that ingested Red chokeberry fruits in New York, Pennsylvania, Ontario, or elsewhere. If this scenario does describe the origin of *A. arbutifolia* in West Michigan, then it could provide support for Reznicek's hypothesis regarding long-range dispersal of coastal plain flora.

A more significant task than describing *how* the shrub came to Michigan, however, might be discerning *when* this species arrived. Past records of *Aronia arbutifolia* in Michigan, which date back to over a century ago, appear to be erroneous. Many of these identifications had been made before the hybrid was described, when floral keys relied on leaf pubescence to distinguish the tomentose-leaved *A. arbutifolia* from the glabrous *A. melanocarpa.* When Emma Cole included Red chokeberry in *Grand Rapids Flora*, for example, she was almost certainly using degree of leaf pubescence as a determining trait during her spring-time field surveys, when fruit formation was still months away (Cole 1901). But it is difficult—if not impossible—to say with certainty that Red chokeberry was never native to Michigan. However, if Red chokeberry has been a longstanding component of Michigan's flora, given the clear morphological differences between *A. arbutifolia* and both *A. melanocarpa* and *A. prunifolia*, we would expect it to have been documented at some point in the past, unless it was very rare and local.

Another possibility, and perhaps the most plausible one, is that the Townsend park shrubs are recent arrivals, and that *Aronia arbutifolia* is simply expanding its range, perhaps in response to climate change. If climate change is in fact influencing the northern and northwestern range expansion of *A. arbutifolia*, then we would expect to see increasing frequencies of the shrub in Kentucky and other places where it is considered infrequent or absent. A 2003 discovery of Red chokeberry in southwestern Ohio, a state record collected from Clermont County (Gardner et al. 2005), might fit the pattern of northward range expansion. Interestingly, two other state records were found in association with the Clermont County discovery, *Bartonia paniculata* (Twining screwstem) and *Woodwardia areolata* (Netted chain fern) (Gardner et al. 2005), both of which are listed in Reznicek's (1994) paper as disjunct coastal plain species that occur in southwestern Michigan. The presence of a disjunct community of flora at the site in Clermont County may indicate a more complex and potentially integrated interaction between climate change and the distribution of coastal plain species, especially if the populations in southwestern Ohio have only recently arrived to the area. If climate change is expanding the ranges of coastal plain flora, then we would expect to see increasing frequencies of *A. arbutifolia* and other coastal

plain species occurring in the 'hotspots' defined by Reznicek (1994), or, conversely, in new areas outside the classically recognized regions of disjuncts.

Further insight into the origin of this shrub could be gained through genetic and molecular analyses. If the molecular composition of our Kent County *Aronia arbutifolia* is found to be similar to representative individuals from Ohio or from other regions close to Michigan, a recent dispersal event from that particular population would be the most likely explanation. But if the Kent County shrubs are notably distinct, such a finding would support the long-term presence of an indigenous Michigan population. A more thorough examination of herbarium specimens from the Great Lakes region and elsewhere could also be valuable in determining whether or not *A. arbutifolia* ever occurred in the state prior to its recent discovery in West Michigan.

Genetic comparisons between local *Aronia prunifolia, A. melanocarpa,* and *A. arbutifolia* could also add clarity to the debate over the relative uniformity or variability of the *Aronia* genus in this region. Both diploid and polyploid populations of *A. arbutifolia* are known to exist along the Atlantic Coast (Holvmam 2004; Brand 2010), and knowing the ploidy level of the Kent County shrubs as well as other molecular traits may provide information as to their potential involvement in local genetic introgression within this enigmatic *Aronia* complex.

CONCLUSION

Trying to understand the presence of a recently discovered stand of *Aronia arbutifolia* in Michigan raises several possible explanations, each with its own set of implications. Its presence in an area known to be a 'hotspot' for coastal plain disjuncts may support the possibility that an indigenous population of *A. arbutifolia* has existed in Michigan for some time. However, in the present context of climate change, and given that the discovery of the species in Ohio is also recent, we think it is more likely that this species is a recent arrival from the southern or eastern United States. If this is indeed the case, then *A. arbutifolia* could either be expanding its range opportunistically or, more complexly, doing so in a manner that follows the patterns of the disjunct coastal plain species. It remains to be seen whether this shrub represents a vestige of an undisturbed Michigan ecosystem or a harbinger of a warming climate—molecular analyses could help illuminate this and some of the many other unknowns surrounding *Aronia*. If history is any indication, future investigations into this enigmatic genus will elicit more questions than answers.

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EFFECT OF SELECTION LOGGING ON *CAREX ASSINIBOINENSIS* W. BOOTT IN A NORTHERN HARDWOOD STAND

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ABSTRACT

A population of *Carex assiniboinensis* W. Boott (Assiniboia sedge) was monitored during the season before and for six years following a winter selection harvest in a sugar maple-eastern hemlock-black cherry stand on the Ottawa National Forest in the Upper Peninsula of Michigan. A mean increase in sedge presence of 136% was observed over the seven years of monitoring. General linear regression of sedge presence data indicated a significantly positive trend over the natural log-transformation of time. Results indicate that canopy opening from winter selection logging in northern hardwood forests may benefit populations of this threatened species.

KEYWORDS: *Carex assiniboinensis*, Assiniboia sedge, selection logging, threatened species, Michigan

INTRODUCTION

A population of *Carex assiniboinensis* W. Boott (Assiniboia sedge) was monitored during the season before and for six years following a winter selection harvest in a closed-canopy sugar maple-eastern hemlock-black cherry stand on the Ottawa National Forest in the Upper Peninsula of Michigan. The site is relatively flat, dissected by a ravine associated with an intermittent stream. Soil is a sandy loam with cobbles on the surface; litter accumulation is thin, typically less than 2–3 cm. The understory is sparse, about 5% cover, mainly young sugar maple with occasional *Lonicera canadensis* (American fly honeysuckle). Ground cover is also sparse, with *Dryopteris intermedia* (intermediate woodfern) as the most common associate. The sedge forms solid patches in many parts of the site.

Considering *Carex assiniboinensis'* status as a state threatened species, typically a 250-foot buffer would have been established around the area covered by the species. Within the population area plus the buffer zone, logging and other ground-disturbing activity would have been prohibited (e.g. USDA Forest Service 2004). The population, however, was not discovered until after the timber sale contract was awarded. Since harvest was already contracted, the Ottawa

FIGURES 1A AND 1B. *C. assiniboinensis* at the study site.

National Forest Botany Program designed a monitoring program to investigate potential effects of overstory selection logging on *C. assiniboinensis*. In addition, to potentially lessen impacts to the sedge population, harvest activity was delayed until snow cover was at least six inches.

FIGURE 2. Location of the study site.

C. assiniboinensis is a perennial sedge in the Cyperaceae family (Figures 1a and 1b). It is easily identified by its long above-ground vegetative shoots (stolons) that can extend up to 2 meters in length, at the end of which new plants form (Bernard 1959; Tolstead 1946; Hipp 2008; USDA NRCS 2012; Voss and Reznicek 2012). The stolons are observable in late-summer, while flowering usually occurs in June and July (Penskar and Higman 1999).

C. assiniboinensis is found on moist sites, in mesic deciduous and mixed forests, floodplains, and river banks. Its native range extends from northern Iowa in the south, southeastern Saskatchewan in the west, and east to the Lake of the Woods region of Ontario near the southern border with Manitoba, and the Upper Peninsula of Michigan (Penskar and Higman 1999; Flora of North America Editorial Committee 2002; USDA NRCS 2012). Michigan is the only state in which the plant is listed as threatened; its conservation status is imperiled (S2) in Michigan, Ontario, and Saskatchewan, and vulnerable (S3) in Manitoba and Iowa (NatureServe 2012). According to the Michigan Department of Natural Resources, it has a coefficient of conservatism of nine (on a scale of ten); that is, it is believed to have high fidelity to a natural community that persists in a state similar to pre-European settlement (Herman et al. 2001).

Effects of overstory management on *C. assiniboinensis* populations are poorly understood. Tolstead (1946) and Bernard (1959) hypothesized that stolon growth is encouraged by light, but no research since that time has confirmed whether an increase in light would contribute to population growth. Bernard (1959) also speculated that soil moisture and other characteristics or weather patterns could affect the degree of stolon formation. He believed that the prevalence of stolons in *C. assiniboinensis* populations in North Dakota was due to long-standing woodland management and perhaps grazing. The Michigan Natural Features Inventory recommends that until the effects of timber harvest on *C. assiniboinensis* populations can be better understood, logging should be avoided

altogether or at least limited to selection cutting during winter months (Penskar and Higman 1999). In this study, it was hypothesized that sedge growth could be promoted as the result of increased light penetration following the creation of canopy gaps. This hypothesis was formed based on presence of the sedge on old skid trails in the Ottawa National Forest.

METHODS

The surveyed population of *C. assiniboinensis* covers a roughly U-shaped area of approximately five to ten acres located in Beechwood Quadrangle in Iron County, MI (T44N R36W S31) (Figure 2). The first monitoring was conducted in September of 1999 and was carried out every September through 2005. Harvesting was conducted in the winter of 1999–2000 on the western portion of the U-shaped area and in 2000–2001 on the eastern portion, with a target residual basal area of 85 square feet per acre in both portions.

Permanent, parallel southeast-northwest running transects were established at randomly spaced distances along the east and west sides of the U-shaped area. The sampling regime used permanent transects in order to (1) be able to monitor changes in the population over time, and (2) allow for the use of a fewer number of sampling points than would be required to meet the same level of accuracy in non-permanent transects (Elzinga et al. 1998). Ten transects were established on the west side and six on the east side. From the fixed starting point, sampling along each transect started at a random distance between one and nine meters on the west and one and five meters on the east side. The starting point and subsequent sampling points, which were spaced one meter apart, therefore changed every year. Thirty points were sampled on each transect on the west side and 25 on each transect on the east side. At each point, presence or absence of sedge ramets was recorded. Data are summarized in Table 1. A sum value for each transect was recorded and then the values from west-side transects were normalized to 25 points.

Data were analyzed in SAS software (SAS Institute Inc., Cary NC) using PROC GLM for general linear regressions. General linear regressions were used to identify a trend in sedge presence following harvest. The data were analyzed as one data set, with year one as the season before harvest for the west (1999–2000) and the east (2000–2001) sides. A single analysis was conducted on monitoring data from the six years following harvest for the west transects and from the five years following harvest for the east transects. Year seven only included data from the west transect. Results were considered significant at $p < 0.05$.

TABLE 1. Mean and standard error values for sedge presence (as ramets) on all transects. Year 1 is the year before harvest. n=16 for years 1 through 6. n=10 for year 7.

Year	Mean	Standard Error
1	8.44	1.04
2	10.00	1.25
3	16.44	1.37
4	17.13	1.23
5	18.75	1.11
6	19.19	1.02
7	19.99	1.42

RESULTS & DISCUSSION

A mean increase in sedge presence of 136% was observed over the seven years of monitoring (Figure 3). A linear regression equation was used to model the effect of time on sedge presence using the natural log of year of survey as the independent variable and sedge presence as the dependent variable for each individual transect and for the mean value of all transects. In order to analyze the response of the sedge following logging, only the data from the second (2000)

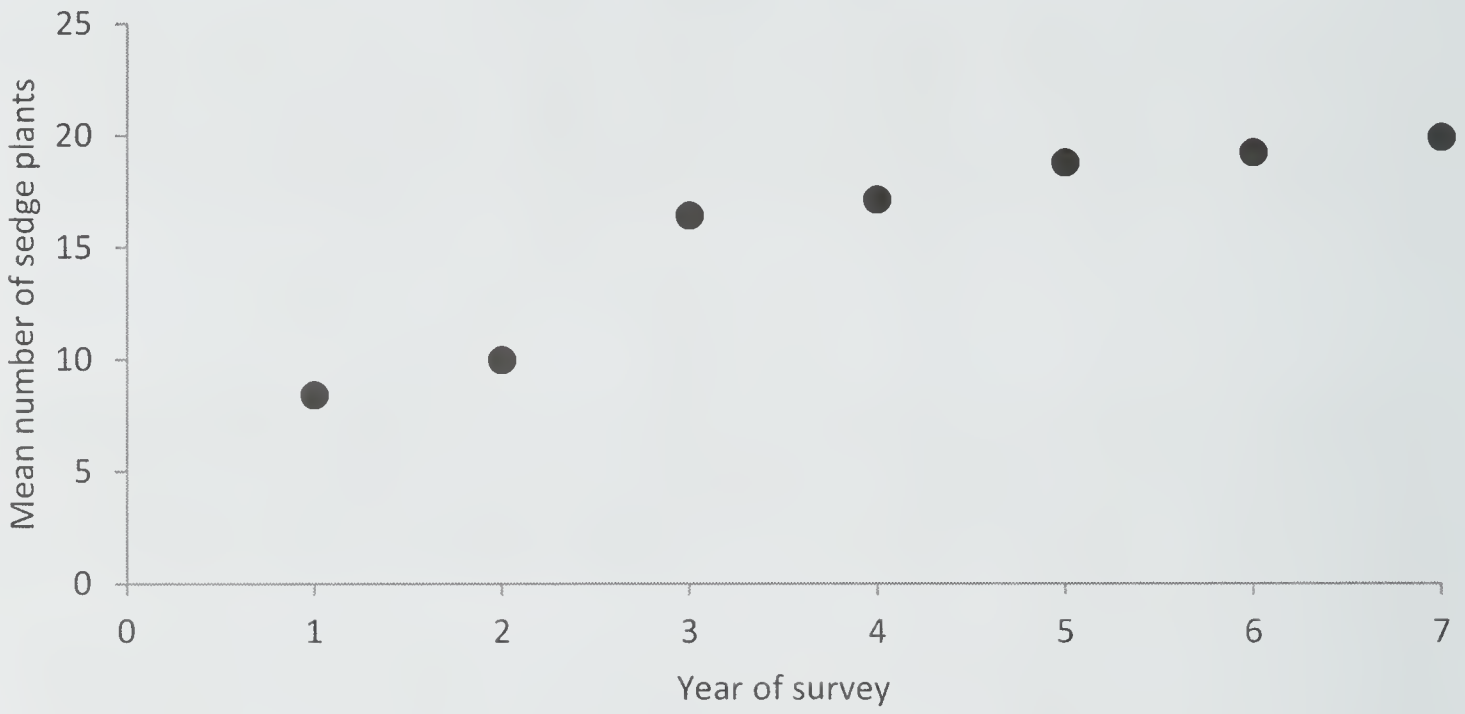

FIGURE 3. Mean number of sedge ramets per transect over the seven years of monitoring. n=16 for years 1 through 6. n=10 for year 7.

through seventh year (2005), for the west side, and the third (2001) through seventh (2005) year for the east side, were used. The regression analysis showed a significant positive trend in mean sedge presence over time ($R^2 = 0.89$; $p = 0.005$) (Figure 4).

Results indicate that winter selection logging in a northern hardwood forest where *C. assiniboinensis* is present had the effect of increasing sedge cover, at least over the short term (as the canopy continues to fill in and light decreases, the sedge population may decrease). Although we did not record size or maturity of plants observed at the sample points, we assume that the observed increase in total cover is due to vegetative reproduction, particularly via the characteristic stolons, rather than from seed. Repeated recruitment from seed is less common

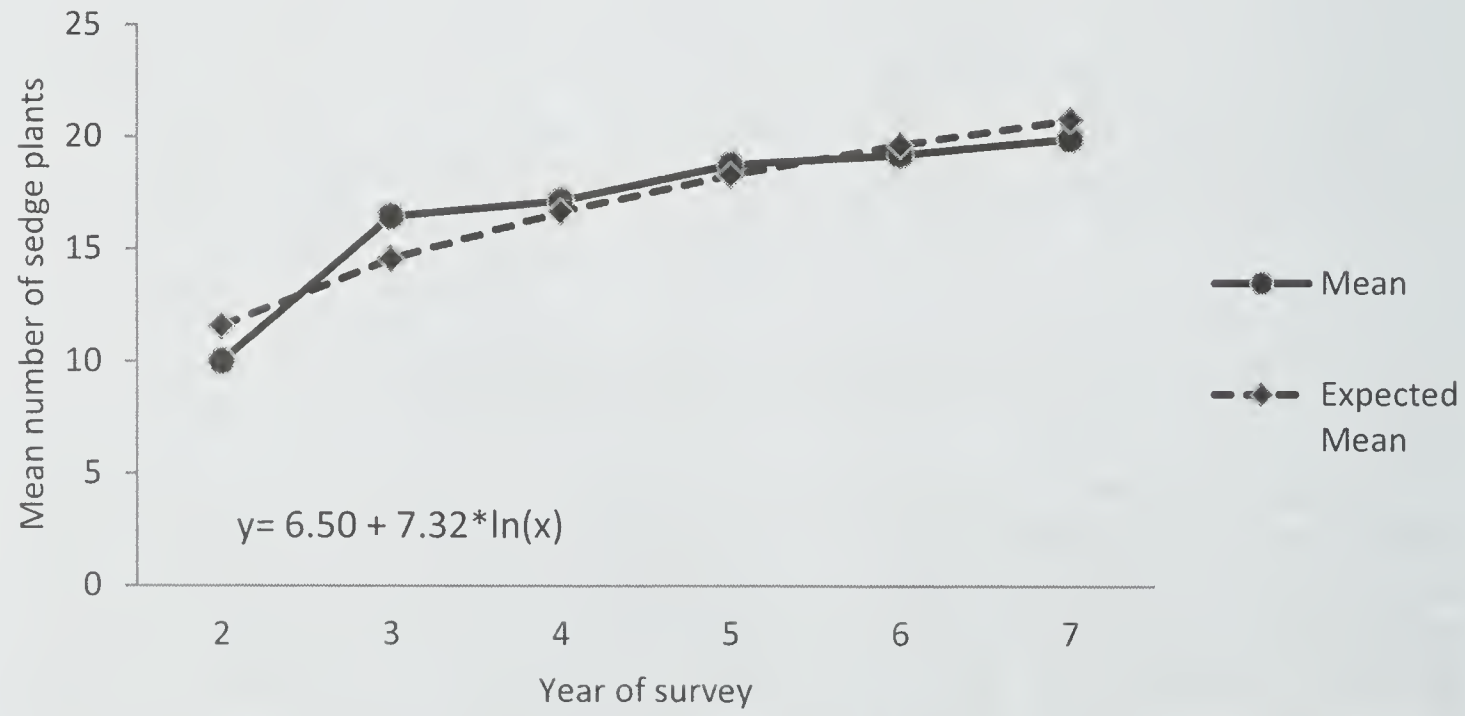

FIGURE 4. Linear regression of sedge ramets as a function of time. x = year of study beginning with 2 = first season after harvest.

in woodland clonal plants where vegetative reproduction typically dominates (Eriksson 1989). An increase in dominance of *C. assiniboinensis* in relation to other species was also observed in the field.

This result is consistent with research (Schultz 1988) on the Hiawatha National Forest, also in Michigan's Upper Peninsula, which found that a selection harvest in mesic hardwoods caused a flush of reproductive effort, with an increased number of fertile culms, in *Carex novae-angliae*, another state-threatened sedge with a coefficient of conservatism of 9. However, this treatment did not result in an increase in total sedge cover.

Increased penetration of light to the forest floor is likely a factor in supporting sedge growth. Studies of the effects of canopy gaps on understory vegetation cite the increase in light penetration as a causal factor in increased ground cover following selection cutting (McComb and Noble 1982; Reader and Bricker 1992). Tolstead (1946) and Bernard (1959) both noted increased stolon formation in *Carex assiniboinensis* populations with increased light.

Limiting harvest activities to winter months also could have contributed to the positive response of the sedge. Harvesting over exposed ground causes soil disturbance and compaction, which can change microclimates and site suitability for understory plants (Brais 2001). Restricting logging to winter months over snowpack or frozen ground results in less impact on understory abundance and percent cover than when logging is conducted during summer months. Species that are more vulnerable to disturbance (coefficient of conservatism >6) are also less likely to be found on summer-logged sites (Wolf et al. 2008). The high coefficient of conservatism (9) attributed to *C. assiniboinensis* (Herman et al. 2001) suggests that if logging was not restricted to the winter, different results might have been observed in this study.

The results indicate that winter selection logging in hardwood forests can have a positive impact on populations of *C. assiniboinensis*, at least in the short term. Based on this study, it may not be necessary to exclude selection cutting from an area where *C. assiniboinensis* is present, despite its threatened status. Without more research, it is advisable to limit harvest activities to winter months over several inches of snow.

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NOTEWORTHY COLLECTION

Michigan

Lygodium palmatum (Bernh.) Swartz—climbing fern, Hartford fern

Previous Knowledge. *Lygodium palmatum* is perhaps best known as the subject of Henry David Thoreau's affection and titling as "our most beautiful fern". He secreted a colony's location in Concord, Massachusetts, from all but a few close friends. It was 120 years later that the legendary colony was found by botanists (Angelo 1985). Considered local and rare throughout its core eastern range from New England to Mississippi, *Lygodium* is reported locally abundant only in parts of Kentucky and Tennessee where, like the collection reported here, it grows in moist, acidic soils (Flora of North America 1993).

FIGURE 1. Habitat of *Lygodium palmatum* Van Buren County, Michigan. Copyright James G. Krause

FIGURE 2. Detail of Sterile Pinnae on *Lygodium palmatum*. Copyright James G. Krause

Previous to this collection, Michigan's only known station of *Lygodium* was in the Gourdneck State Game Area in Portage, Michigan. Located and collected by Richard W. Pippen and Western Michigan University students in 1965, it represented, in addition to the only Michigan occurrence, the northern-most station of the species in the United States by 250 miles (Pippen 1966). This colony is documented to have persisted as of 1999 (McKenna 2004) but recent accounts state it has become increasingly difficult to locate and may be extirpated from this location (Mike Penskar MNFI and Todd Barkman WMU, pers. comm. Sept. 13, 2012 and Oct. 23, 2012, respectively). In Michigan the plant is listed as Endangered with a rarity ranking of S1 (critically imperiled).

Significance. In addition to representing the second known station of *Lygodium* in Michigan, this collection now documents, at 19 kilometers northwest of the Portage station, the most northerly station in the United States. As already noted it may also be the *only* station in Michigan currently.

The colony reported here is vigorous and larger, at 34 m^2, than the colony size of 4 m^2 noted by Pippin. Growing as a dominant species of this relatively large area, on undeveloped private land, suggests this colony is not introduced. This new discovery, growing in sandy soil near a sphagnum-floored shrub swamp of *Toxicodendron vernix*, *Osmunda cinnamomea*, and *Osmunda regalis*, shares many habitat features known to the Portage *Lygodium* station (Fig. 1). It is tantalizing to think that these habitat echoes could lead to more *Lygodium* discoveries in Michigan.

FIGURE 3. Detail of Fertile Pinnae on *Lygodium palmatum*. Copyright James G. Krause

Diagnostic Characters. *Lygodium* is a distinct and easily recognized plant; clearly a fern but unlike any other native fern in appearance and habit. It has sterile evergreen pinnae, ovate, deeply and palmately lobed, that fork on 1–2 cm stalks resembling two human hands about to clap (Fig. 2). The fertile pinnae are smaller than sterile pinnae, borne at the tips of the "vines" from late summer to late fall, irregularly forked or lobed and notably smaller and more finely palmate than sterile pinnae (Fig. 3) (Flora of North America 1993)(Cobb, et. al. 2005).

Arguably most unique is it's twining and climbing, vine-like habit (Fig. 4). The collection reported here represents a colony of >1000 sprouts that primarily twine around each other forming mats over stunted *Sassafras albidum*. The collected specimen was one of only two climbing plants noted at the time of collection.

Specimen Citation. Van Buren County, Almena Township. Low, moist, open transition zone between shrub swamp and dry upland forest; Thetford loamy sand, pH: 3.9. Twining 55.9 cm vertically on *Acer rubrum* sapling. Sprouting profusely to form 34 m^2 colony. Dominant understory species; minority understory associates: *Sassafras albidum*, *Gaultheria procumbens,* and *Diphasiastrum digitatum*. Overstory *Acer rubrum*. Surficial rhizomes dark brown with red bristles. Rare. September 30, 2012. James G. Krause 1 with Grant D. Krause. Collected Under Michigan DNR Permit #2015. (MICH).

FIGURE 4. Twining and climbing habit of *Lygodium palmatum*. Copyright James G. Krause

Special thanks to Mike Penskar MNFI and Anton A. Reznicek MICH for their help and guidance with regard to this rare find, and to Todd Barkman for his comments on this manuscript.

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On the cover: *Cattail marsh bordering Cedar Creek at Pierce Cedar Creek Institute, Hastings, MI, summer 2012. (Photograph by Alex Graeff).*

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SUITABILITY OF *CARDAMINE CONCATENATA* (MICHX.) SW. AS AN INDICATOR SPECIES ON THE OTTAWA NATIONAL FOREST

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ABSTRACT

The cutleaf toothwort (*Cardamine concatenata)* is one of four Management Indicator Species monitored on the Ottawa National Forest. It is a perennial spring ephemeral used to indicate effects of forest management, particularly timber harvest, on site conditions in northern hardwoods, and on populations of forest understory spring wildflowers. Surveys were conducted in 70 treated and 61 non-treated stands. Stands were monitored for abundance of *C. concatenata* as well as abundance of three other spring ephemerals (*Cardamine diphylla, Claytonia caroliniana,* and *Allium tricoccum).* Additional site characteristics that could affect *C. concatenata* abundance were monitored, including micro-topography, ground flora, earthworm disturbance, and deer browse. Analysis assessed both the impact of management on site conditions and the suitability of using *C. concatenata* as an indicator species. Results showed no significant relationship between hardwood management and *C. concatenata* abundance. While *C. concatenata* was representative of the other three spring ephemerals monitored, its relative scarcity across the Ottawa National Forest raises questions as to its suitability as a Management Indicator Species.

KEYWORDS: *Cardamine concatenata, Dentaria laciniata,* Management Indicator Species, forest management, spring ephemerals, northern hardwoods

INTRODUCTION

Indicator species are used for efficient monitoring of the status of flora, fauna and environmental conditions in a particular area, but their use in ecosystem and biodiversity management has been widely critiqued (Niemi et al. 1997; Caro and O'Doherty 1999; Landres et al. 1988; Lindenmeyer et al. 2000; Carignan and Villard 2002; Nylen 2011). The USDA Forest Service uses Management Indicator Species (MIS) in the monitoring of effects from management activities on plant and animal populations. The cutleaf toothwort, currently referred to as *Cardamine concatenata* (Michx.) Sw. but previously known as *Dentaria laciniata* Muhl. ex Willd., is used as an indicator of impacts of northern hardwood forest management, particularly harvesting, on woodland wildflower populations on the Ottawa National Forest (ONF). As a spring ephemeral species representative of that guild, *C. concatenata* was selected as an indicator because of its habitat specificity to mesic hardwood stands, its sensitivity to disturbance, its slow

dispersal rate, and its presumed non-palatability to deer. In this paper, results from monitoring *C. concatenata* and three other spring ephemerals, in stands with different harvest histories, are analyzed to assess both the impact of hardwood management on site conditions and the suitability of *C. concatenata* as a management indicator.

Herbaceous Species as Ecosystem Health Indicators of Forest Management

There are a number of different types of, and uses for, indicator species. One such type, ecosystem health indicator species, is used to obtain insights about the environmental conditions of the resources upon which species depend (Landres et al. 1988; Caro and O'Doherty 1999). Given their known site or resource requirements, the presence or abundance of plant species on a site is informative of the moisture, soil, temperature, light and other conditions at that site. There are, however, various factors unrelated to habitat quality, such as browse, dispersal rates, and history of disturbance (Kashian et al. 2003) that can affect the populations of indicator species without necessarily affecting related species. Given the diversity of factors that affect populations, it can be difficult to assess the impact of each on an indicator species and to correlate observations of indicator species populations to environmental conditions (Landres et al. 1988).

Natural resource managers use ecosystem health indicators to monitor the impacts of active management on site conditions at the stand and landscape levels. Disturbance resulting from timber harvesting can cause a number of changes to soil productivity, moisture, light regimes, and temperature on the forest floor. When harvesting activities are not carried out over snow or frozen ground, skidder traffic can cause soil compaction and removal of the litter layer, resulting in lower infiltration rates and increased erosion (Grigal 2000; Brais 2001; Zenner and Berger 2008). Opening the canopy allows for increased light penetration to the forest floor, causing an increase in temperature (Brooks and Kyker-Snowman 2008) and cover of herbaceous species (Metzger and Schultz 1984; Scheller and Mladenoff 2002). While changes in soil moisture vary depending on harvest intensity and soil disturbance, soil moisture is generally believed to increase following tree removal due to lower transpiration rates (Bormann and Likens 1979; Stoffel et al. 2010).

The degree of disturbance and the rate of recovery of site conditions and stand composition and structure in hardwoods are affected by the intensity and frequency of harvest (Metzger and Schultz 1984; Fredericksen et al. 1998; Zenner et. al. 2006). Group selection and clear-cutting cause significant changes immediately following harvest, including a shift in species composition from more sensitive herbs to ruderals (Meier et al. 1995; Zenner and Berger 2008). Intensively harvested northern hardwood sites are slow to recover to pre-harvest conditions. The impact of single-tree selection and thinning is less severe because uneven-aged management regimes more closely mimic natural stand succession (Barnes et al. 1998; Zenner et al. 2006). Under uneven-aged management, initial recovery may begin within three to five years (McComb and Noble 1982; Metzger and Schultz 1984; Reader and Bricker 1992). As succession progresses and light penetration to the forest floor decreases over time, the site gradually re-

sembles pre-harvest conditions (Barnes et al. 1998). As time post-harvest increases, species composition and abundance will be expected to change and reflect the process of stand succession.

Stand-level disturbance occurs less frequently under natural succession than under timber management. Cutting cycles are typically 10 to 20 years in northern hardwoods in the upper Great Lakes area (Martin and Lorimer 1996), although closer to 20 on the Ottawa NF. Even the longest cycles impose changes at a faster rate than natural processes (Barnes et al. 1998). With increased frequency of disturbance, understory species, especially those characteristic of late-successional forests, are less capable of recolonizing a site (Brewer 1980; Duffy and Meier 1992; Tonteri 1993).

When using herbaceous plants as indicators of management impacts on site conditions, it is recommended to use species that are sensitive to change, fairly specialized in their habitat type and site conditions requirements, and easy to monitor (Caro and O'Doherty 1999). Within each habitat type (dry conifer, mesic hardwood, swamps, etc.), site characteristics such as soil conditions, light availability, and topography vary at the stand level. Plants that favor specific conditions, such as shade-intolerant species that colonize canopy gaps, are good indicators of those conditions and for inferring stage of stand succession (McLachlan and Basely 2001). Species that are sensitive to change are used to correlate abundance of the indicator species to the degree of disturbance at a site (Graul and Miller 1984). Species that are so sensitive or specialized that they are rare are not good indicators because their low populations are difficult to find and monitor and are incapable of providing useful monitoring data (Landres et al. 1988). Considering that efficiency is a principal motivation for relying on indicator species, species selection should take into account their ease of monitoring. Species should be easily identifiable, their populations should be accessible for survey, and their population levels should be high enough that absence is not a problem (Caro and O'Doherty 1999).

The ability to directly correlate specific site factors to abundance of an indicator species is essential to the utility of indicator species (Pearson and Cassola 1992). Susceptibility to external factors, such as deer browse, distorts this ability and weakens the utility of an indicator species (Landres et al. 1988). Species with low seed dispersal distances, such as ballistic or ant dispersal, have been proposed as good indicators of stand recovery because they are slow to recolonize a site after disturbance (Lambeck 1997). Their limited dispersal ability is an external factor that can prove misleading, however, if the species' ability to recolonize is limited, not by recovery of site conditions, but by an absence of remnant populations on sites within the same geographic area (Dzwonko and Gawrónski 1994). On sites where soil, moisture, and light conditions have recovered to a suitable level, species composition recovery still may be limited by the slow dispersal rates of certain species (Racke 2010). Therefore, the use of such herbaceous plants as health indicators can confound analysis of management impacts; even when site conditions have recovered, ground flora may never fully resemble species composition prior to the previous harvest and earlier disturbances.

The Forest Service MIS System

The USDA Forest Service uses MIS to monitor the effects of forest management on species populations and viability. In order to comply with the 1976 National Forest Management Act (NFMA) "biodiversity mandate," as it is commonly referred to, the 1982 NFMA Planning Rule (36 C.F.R. § 219.19 200) created the MIS system. The "biodiversity mandate" requires that all National Forests "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives" (16 U.S.C. § 1600(g)(3)(B)). Challenged with managing for multiple uses, including plant and animal diversity, indicator species are relied upon where monitoring of all plant and animal species would be prohibitively costly.

The MIS system has been criticized for being ineffective in fulfilling the biodiversity mandate. The use of population indicators has been widely criticized and is no longer grounded in the scientific literature (Owen 2010; Nylen 2011; 36 C.F.R. § 219 2012). Criticism of the use of MIS has focused on the inability of a select group of indicator species to account for the full diversity of plant and animal life on each national forest. The complexity inherent in managing for the diversity of species and their resource dependencies makes it challenging for the Forest Service to provide standardized protocols that offer sufficient guidance, but are also sufficiently flexible to be adapted to the conditions at each national forest (Nylen 2011).

Cardamine concatenata *as an indicator of northern hardwood forest management impacts*

On the ONF, *C. concatenata* is one of four species or species suites monitored under the MIS system since 2006 when the Forest Plan was revised. *C. concatenata* is a low-growing native spring ephemeral in the mustard family (Figure 1). It is found in the understory of northern hardwood stands on nutrient-rich sites. *Cardamine concatenata* population trends are used to monitor impacts of timber harvesting of northern hardwood stands on species populations and site conditions.

Spring ephemerals are regarded as good indicators of site conditions because they require moist conditions, nutrient-rich soil, and an absence of competition from other ground flora in early spring (Eickmeier and Shussler 1993; McLachlan and Basely 2001). Since their life cycle begins before leaf emergence, their presence is influenced, not so much by canopy cover, as by soil characteristics, moisture, and temperature on the forest floor (Bratton 1994). Disturbance can result in their absence from a site either as the direct result of harvest or indirectly due to changes in site conditions associated with hardwood management activities (Dzwonko 1993; Meier et al. 1995). Spring ephemerals typically have limited seed dispersal ability, through ant or ballistic methods, meaning that once absent from a site, they are slow to recolonize (Dzwonko and Loster 1992). Their absence from or decline within a site following timber harvest is considered an indication that management activities resulted in deleterious changes on the forest floor, and their recolonization may be an indicator of site recovery if a seed source is available.

Of the spring ephemerals found in northern hardwood stands on the ONF, *C. concatenata* was chosen for monitoring because of its sensitivity to disturbance,

Figure 1. *Cardamine concatenata* at a study site on the Ottawa National Forest.

ease of monitoring, and its association with the hardwood cover type. Since deer are presumed to be less likely to browse on plants in the mustard family, this external factor might not distort monitoring data. *Cardamine concatenata* was chosen over the two-leaf toothwort (*Cardamine diphylla),* another mustard, because *C. concatenata* is easier to distinguish and it is also a host plant for the West Virginia White butterfly (*Pieris virginiensis*), a species on the Regional Forester's Sensitive Species list for the ONF. The leaves of *C. concatenata* turn yellow during senescence in late May or early June, facilitating spotting plants during field surveys. Vegetative reproduction and ballistic dispersal limit its range and ability to recolonize sites after disturbance. *Cardamine concatenata* is usually found in northern hardwood stands, focusing insights from monitoring to conditions in the northern hardwood habitat type across the ONF.

METHODS

Based on the known habitat preferences of *C. concatenata*, the Ottawa National Forest Geographic Information System (GIS) was used to identify northern hardwood stands on nutrient-rich sites. *Acer-Viola-Osmorhiza* (AVO) and *Acer-Osmorhiza-Caulophyllum* (AOC) ecological landtype phase map units were chosen because they designate rich, moist soils (Coffman et al. 1984). Stands identified as northern hardwoods had sugar and red maple, hemlock, yellow birch, and basswood as dominant tree species. Sites fulfilling both of these characteristics were considered to be suitable habitat for *C. concatenata*. Individual stand management history was identified based on ONF records. Forest management activities included, generally, selection harvests, stand improvements,

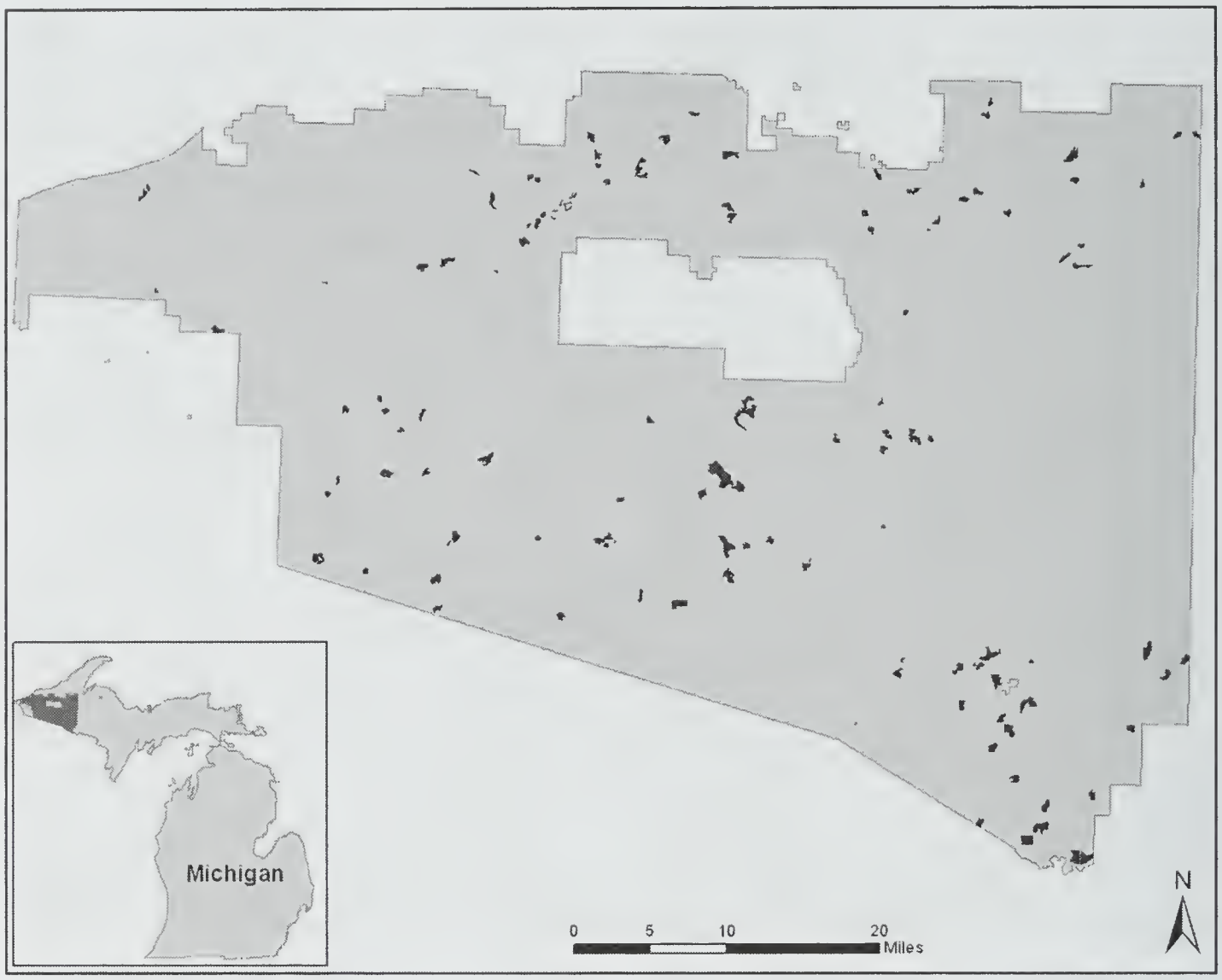

Figure 2. Location of monitored stands across the Ottawa National Forest in Michigan's Upper Peninsula (spatial data from USDA Ottawa National Forest).

and commercial thinning. Three-hundred and twenty-nine non-treated stands totaling 5,668 acres and 165 treated stands totaling 4,636 acres were identified as potential monitoring sites. Treated sites are those that were harvested since the widespread logging that occurred around the end of the 19th century and beginning of the 20th century. For each year of monitoring, a set of treated and non-treated stands that were larger than 35 acres and with easy road access were chosen. Due to soil and moisture conditions on the ONF, northern hardwoods are more prevalent on the south and west portions of the Forest, hence fewer stands were selected for monitoring on the east and north portions (Figure 2).

Starting in 2006, sampling was conducted every year in late May or early June, due to the plant's phenology. The number of stands monitored each year varied depending on staff workloads within the short window of opportunity for monitoring during plant senescence. In each stand, a meander survey was conducted, lasting about one hour (Goff et al. 1982). Abundance, on a scale from 0 (none) to 6 (extensive) and pattern of occurrence of *C. concatenata* were recorded based on observations in the whole stand. On a scale of 0 (none) to 4 (abundant), abundance of *C. diphylla, Claytonia caroliniana* (spring beauty), and *Allium tricoccum* (wild leek) were also recorded. On a scale of 1 (scarce) to 4 (abundant), coarse woody debris, micro-topography, weedy ground flora, and sugar maple regeneration were noted. Dominant weedy ground flora species were identified and recorded. Earthworm infestation level and deer browse on woody species in the stand were each rated as high, medium, or low.

Data collected through 2011 were analyzed in SAS software (SAS Institute Inc., Cary N.C.) using the PROC FREQ and PROC GLM procedures. Because values in some abundance categories were too low to be analyzed using a chi-square test, a Fisher's exact test was used to analyze abundance data of the spring ephemeral plants to other categorical data. In cases where values in each category analyzed were too low to even use a Fisher's exact test, abundance was generalized to "present" and "absent". Results of all tests were declared significant at $P < 0.05$.

A Fisher's exact test was used in the following procedures. Differences in abundance in treated versus non-treated stands were tested on all four spring ephemeral species. Difference in abundance

of *C. concatenata* by harvest type was tested for each activity type. Activity types included single-tree selection cutting, overstory removal cutting, improvement cutting, commercial thinning, and pre-commercial thinning. Presence versus absence of *C. concatenata* was tested against presence versus absence of *C. diphylla, C. caroliniana,* and *A. tricoccum. C. concatenata* presence and absence values were tested against abundance of weedy ground flora, coarse woody debris and micro-topography. A Tukey's Studentized Range test was used to determine if number of years since harvest influenced presence of *C. concatenata*. Number of years since harvest ranged from 5 to 33 (mean = 20.7).

A spatial autocorrelation was used to assess the pattern of *C. concatenata* abundance in each stand monitored across the ONF. ArcGIS 10.1 [Esri Corporation, Redlands CA] software was used. *Cardamine concatenata* abundance was set as the input field, using inverse distance as the conceptualization of spatial relationships parameter and Euclidean distance as the distance method. The data were not standardized.

RESULTS

In the following analysis, *C. concatenata* abundance was correlated with harvest, based on the assumption that *C. concatenata* is a suitable indicator. This assumption is then tested by analyzing the ability of *C. concatenata* to indicate site conditions. Suitability as an ecosystem health indicator species is determined by the ability, first, of *C. concatenata* to represent the other spring ephemeral species and, second, to directly correlate abundance to harvest impacts, controlling for external factors that may also affect population abundance. Sound interpretation of monitoring results requires consideration of factors independent of recent harvest activity.

Effects of harvest on site conditions

The Fisher's exact test showed no significant difference in *C. concatenata* abundance between treated and non-treated stands (P =0.98). The same test was used to determine if the other spring ephemerals that were monitored showed a difference under treated or non-treated conditions. There was no significant difference in *C. diphylla* (P = 0.70), *C. caroliniana* (P = 0.72), or *A. tricoccum* (P = 0.23) abundance between treated and non-treated stands. There was also no difference in *C. concatenata* abundance in relation to time in years since harvest (P = 0.66). The results appear to indicate that harvest was not a factor affecting abundance of spring ephemeral species.

The harvest activities would have produced disturbances that varied in degree and character. The Fisher's exact test showed no significant difference in abundance of *C. concatenata* under five out of the six activity types; the exception is improvement cutting (Table 1). Given that only one of the six harvest types, one with fewer than ten sample points, was statistically significant, it is likely that this is a spurious relationship.

Suitability of C. concatenata *as an indicator*

The Fisher's exact test was used to assess if *C. concatenata* is a good representative of the other spring ephemeral species. The results showed that the relationship between abundance of *C. concatenata* and *C. diphylla* ($P < 0.0001$),

TABLE 1. Relationship between *C. concatenata* and management activity type. n=66, df=6.

Activity Type	Table Probability	*P*-value
Single tree selection cut	>0.0001	0.41
Improvement cut	>0.0001	0.04
Commercial thin	0.0012	0.64
Sanitation cut	0.1207	0.52
Overstory removal cut	0.5606	1.00
Initiate natural regeneration	0.1698	1.00
Pre-commercial thin	0.0092	0.38

Claytonia caroliniana ($P = 0.0014$), and *A. tricoccum* ($P < 0.0001$) was significant. These results indicate that *C. concatenata* is representative of the other spring ephemeral species.

To assess the reliability of using *C. concatenata* as an indicator species, additional factors affecting its abundance were analyzed. *Cardamine concatenata* was found to be absent from 68 out of 131 sites (Figure 3). *Cardamine concatenata* presence versus absence was not significant in relation to coarse woody debris ($P = 0.73$), micro-topography abundance ($P = 0.09$), or weedy ground flora abundance (i.e. competition) ($P = 0.26$). Results from the spatial autocorrelation, used to assess the pattern of *C. concatenata* abundance in each stand monitored, showed a clustering pattern across the ONF ($P = 0.0008$, $z = 3.368$). The data were not standardized because of the low variance of 0.0045. The analysis shows that on a range from 0 (absent) to 6 (extensive), sites with the same abundance values are located close together on the landscape.

DISCUSSION

If it is assumed that *C. concatenata* is a good indicator of site conditions, then the statistical similarity of spring ephemeral abundance in the treated and non-

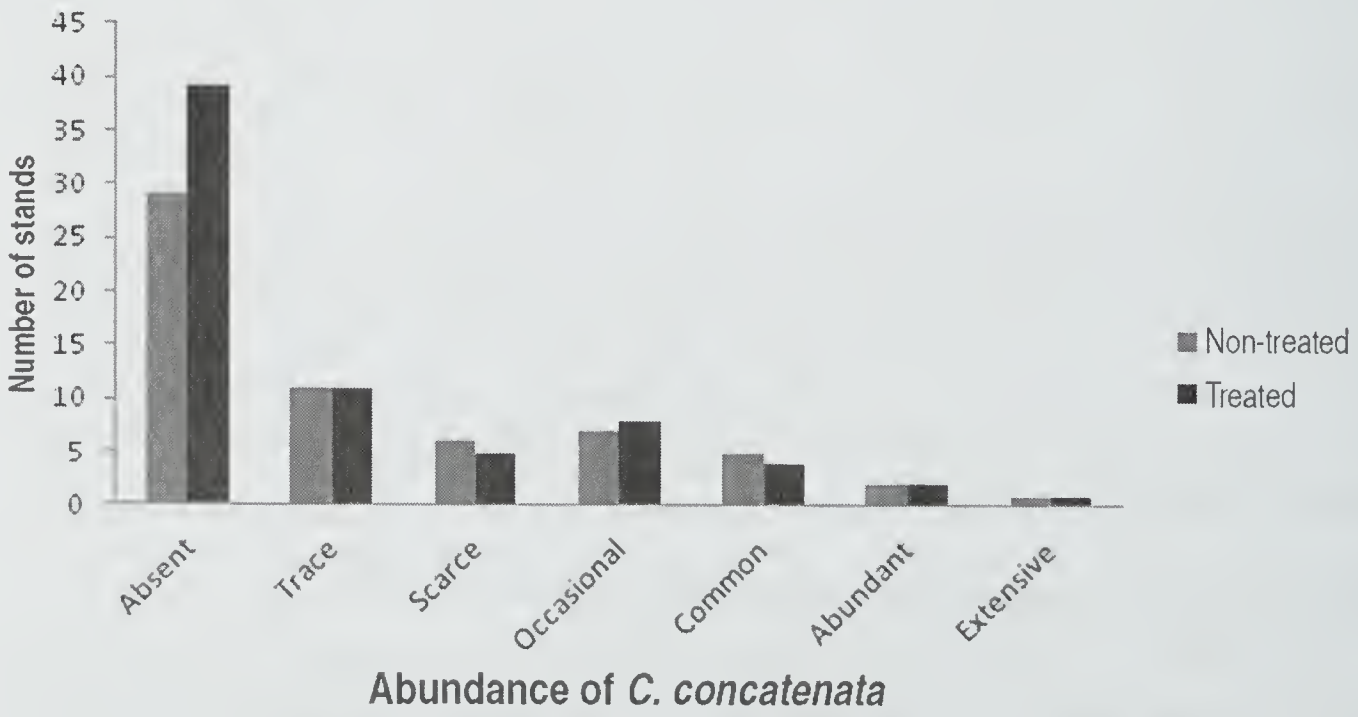

Figure 3. Abundance of *C. concatenata* in treated and non-treated stands. n=131.

treated stands indicates that harvest activities are not negatively affecting site conditions in northern hardwood stands on the ONF. The harvest techniques, protective design criteria, and best management practices employed by the ONF thus would not be expected to significantly alter soil conditions or herbaceous plant composition. The expected increase in soil moisture following harvest (Bormann and Likens 1979; Stoffel et al. 2010) would provide the moist conditions required by spring ephemerals. Restriction of harvesting to winter months prevents the soil compaction and organic layer disturbance that are the most detrimental to site conditions (Grigal 2000; Brais 2001; Zenner and Berger 2008). Single-tree selection and thinning, as opposed to group selection and clear-cutting, are known to more closely mimic dynamics within non-treated stands (Zenner et al. 2006).

Results showed that *C. concatenata* is representative of the other spring ephemerals and that as a group there was little distinction between the four spring ephemeral species as they related to other factors. None of the spring ephemerals appeared to be affected by harvest activities. *Cardamine concatenata* therefore appears to be representative and an adequate indicator of the other three spring ephemerals.

The ability to correlate *C. concatenata* abundance to impacts of harvest on site conditions is weakened by the low population levels of the plant across the surveyed stands. *Cardamine concatenata* was identified at only 68 out of 131 sites, and on sites where it was present, abundance was low (Figure 3). Where present, the low population levels make it difficult to determine the degree to which forest management may be a factor affecting abundance. Its widespread absence indicates that factors independent from recent treatments are affecting *C. concatenata* abundance. Coarse woody debris, micro-topography, and weedy ground flora cover did not have an impact on *C. concatenata* abundance and were not useful in explaining *C. concatenata* population dynamics.

A plausible explanation for the widespread absence of *C. concatenata* is that as a result of its limited dispersal ability, it may still be recovering from the intensive disturbance that occurred at the turn of the 20th century (USDA Forest Service 2006). At that time, forests across much of the Upper Peninsula of Michigan were clearcut for their valuable timber and then burned over. In the same period, over multiple years, fire swept through many parts of the area currently within the ONF, with at least 20% burning three to four times (Karamanski 1984; Karamanski 1989). Following such intensive disturbance, only isolated populations of *C. concatenata* likely survived. Stands can take over a hundred years to recover from intensive disturbance (Brewer 1980; Duffy and Meier 1992; Tonteri 1993), and recovery of *C. concatenata* populations would be limited by their dispersal ability. Ballistic dispersal of woodland herbaceous plants is on average only 1.5 meters per year (Cain et al. 1998). With the source for recolonizing *C. concatenata* plants limited to remnant populations, recovery of the plant across the approximately one million acres encompassed in the ONF may still be in progress.

The clustering of *C. concatenata* populations across the ONF indicates that population abundance is correlated to geographic position. Without survey data covering a greater portion of stands across the ONF or population data from be-

fore the acquisition of the ONF, a more precise mapping of *C. concatenata* populations in relation to late-successional stands is not possible. The spatial autocorrelation results do illustrate that absence of *C. concatenata* from sites may be a factor of geographic position on the forest, suggesting that populations could still be in the process of recolonizing areas of the ONF.

While the limited dispersal of spring ephemerals is considered to enhance their usefulness as indicator species (McLachlan and Basely 2001), it may prove misleading in cases where absence from a site is better explained by their slow rate of recolonization than site conditions. In western Kentucky, transplant of spring ephemeral species to northern hardwood sites with a history of disturbance resulted in survival and self-propagation, indicating that absence from the site was due to dispersal limitation and not site conditions (Racke 2010). In Poland, landscape analysis of spring ephemeral population recovery determined that close proximity to undisturbed forests was a factor affecting spring ephemeral presence in secondary forests (Dzwonko and Gawrónski 1994). While it is not conclusive that the legacy of logging and fire from the turn of the 20th century are still affecting *C. concatenata* populations, it is one reasonable explanation for the widespread absence of the plant across the ONF.

CONCLUSION

Since 2000, the Forest Service has proposed a number of changes to the original 1982 NFMA Planning Rule. The drafting processes and subsequent rules have taken criticisms of MIS into account. The newest planning rule, effective as of May 2012 (36 C.F.R. § 219 2012), acknowledges that the use of population indicator species is no longer supported in science. The new rule is consistent with previously proposed planning rules that moved away from "management indicator species" (population indicators) to what are termed "focal species," which are meant to serve as indicators of "ecological conditions" and to provide information regarding the effectiveness of the Forest Plan in meeting diversity and ecological sustainability requirements (36 C.F.R. § 219 2012). Under the 2012 Planning Rule the National Forests will have to re-evaluate their monitoring programs by 2016 and determine which species will serve as focal species, some of which may be species that were previously MIS.

Results of this study indicate that *C. concatenata* is not suitable as an indicator species. It has some of the characteristics that are recommended in indicator species, and it is representative of other spring ephemerals. It is selective in its colonization of mesic hardwood sites, sensitive to disturbance, presumed to be avoided by deer, and has limited dispersal ability. However, its limited abundance across the ONF restricts *C. concatenata*'s usefulness. *Cardamine concatenata* is not recommended for continued use as a MIS or for use as a focal species.

Analysis of field data showed no significant difference in *C. concatenata* abundance between treated and non-treated stands. Despite the widespread absence of *C. concatenata* from both types of hardwood stands, this sample ap-

pears to indicate that the ONF is managing northern hardwoods stands for retention of toothwort and other spring ephemerals.

The intensive disturbance that occurred near the beginning of the 20th century may be one significant factor affecting *C. concatenata* absence. Northern hardwood stands may take many years to recover, and on intensively and repeatedly disturbed sites, species composition may forever be altered. Results of this study show that it is difficult to monitor site conditions using health indicators given the complexity of factors that can affect individual species, especially when the species is not widely distributed. This study will help inform future selection of focal species and other indicators on the Ottawa National Forest.

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THE DISTRIBUTION, ECOLOGY, AND CONSERVATION STATUS OF *RUBUS ACAULIS* MICHX. (DWARF OR ARCTIC RASPBERRY) IN MICHIGAN

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ABSTRACT

Rubus acaulis Michx. (dwarf or arctic raspberry) is a dwarf herbaceous perennial plant in the rose family (Rosaceae) characteristic of mesic to hydric open and forested habitats across boreal North America. The species ranges south locally to the conterminous United States, where it is designated a sensitive species by the United States Forest Service in Region 2 in Colorado and parts of Regions 6 and 9 in Washington and Michigan, respectively. *Rubus acaulis* was first discovered in Michigan in 1976, and several additional populations have been documented over the past decade from minerotrophic peatlands in eastern Upper Michigan, extending west to Marquette County. In these habitats, which are classified as patterned fen, northern fen, and poor fen, *R. acaulis* occurs with a consistent group of vascular plant associates, and is typically most frequent on the tops, sides, and margins of *Sphagnum*-dominated hummocks. Despite the recent documentation of several very large populations, the long-term prospects for the persistence of *R. acaulis* in Michigan remain uncertain due to the threat of climate change and associated disruption of ecosystem processes in its peatland habitats.

KEYWORDS: *Rubus acaulis*, Rosaceae, boreal flora, peatland, fen, conservation, climate change, Upper Michigan

INTRODUCTION

Rubus acaulis Michx. (Rosaceae) is a small herbaceous, rhizomatous raspberry (Figure 1), traditionally placed in the polyphyletic subgenus or section *Cylactis* (Raf.) Focke (Alice and Campbell 1999). The species is characterized by largely herbaceous, generally unarmed, short stems; ternate leaves with leaflets rounded at the apex; solitary, showy pink or rose flowers with glandless sepals and pedicels that are borne below (and often hidden within) the leaves; and edible, red, nearly globular fruits (Soper and Heimburger 1982; Gleason and Cronquist 1991; Ladyman 2006). The species is widespread across boreal North America, where it occurs primarily between 50° and 60° latitude (Soper and Heimburger 1982; USDA Forest Service, Eastern Region 2002; Kartesz, BONAP 2011). *Rubus acaulis* is sometimes taxonomically included within *R. arcticus* L.

FIGURE 1. *Rubus acaulis* (dwarf raspberry) in a Michigan patterned fen. Note the large flowers with rose-pink petals and rounded leaflets characteristic of the species. (Photograph by Bradford S. Slaughter, 18 June 2009.)

(as *R. arcticus* L. ssp. *acaulis* [Michx.] Focke), a circumpolar taxon that occurs at high latitudes primarily in Eurasia and Alaska (Hultén 1968; USDA Forest Service, Eastern Region 2002; USDA, NRCS 2012).

In the conterminous United States, *Rubus acaulis* is considered a boreal relict species with isolated populations in alpine regions of Washington, Montana, Wyoming, and Colorado and in peatland habitats in the northern Great Lakes region of Minnesota, Wisconsin, and Michigan (USDA Forest Service, Eastern Region 2002; Ladyman 2006; Kartesz, BONAP 2011; Robert W. Freckmann Herbarium, University of Wisconsin-Stevens Point 2012; MNFI 2013a). In the core of its boreal North American range, *R. acaulis* exhibits broad ecological amplitude, occurring in a variety of generally mesic to hydric habitats, including moist forests, meadows, bogs, muskegs, alpine slopes, tundra, and streambanks (Hultén 1968; Ladyman 2006). In the conterminous United States, it occurs in a restricted subset of habitats, including montane meadows, willow thickets, fens, riparian areas, and *Picea engelmannii* (Engelmann spruce) forests in western states and open to wooded peatlands, especially poor to rich fens, in the northern Great Lakes States (Wheeler and Glaser 1982; Glaser 1992c; USDA Forest Service, Eastern Region 2002; Washington Natural Heritage Program and U.S.D.I. Bureau of Land Management 2005; Ladyman 2006; Smith 2008; MNFI 2013a). Although *R. acaulis* is considered globally secure, the species is listed as imper-

TABLE 1. *Rubus acaulis* distribution, conservation status rank (S-rank; NatureServe 2013), state listing status, and USFS sensitive species status in the United States.

State	S-rank[1]	State Listing Status[2]	USFS Status	Notes	Sources
AK	SNR	None	None	Widespread	Hultén 1968
CO	S1	None	Sensitive, Region 2	Four extant sites and one historical site in the Pike and Arapaho National Forests	Spackman et al. 1997; Ladyman 2006
MI	S1	E	Sensitive, Region 9	See text	MNFI 2007; Voss and Reznicek 2012
MN	SNR	None	None	Core of conterminous U.S. range; documented from 18 counties	Glaser 1992c; MNDNR 2003; Ladyman 2006; Smith 2008
MT	SNR	None	None	Known from five observations in alpine peatlands	Montana Natural Heritage Program 2012
WA	S1	T	Sensitive, Region 6	One extant and one historic site	Washington Natural Heritage Program and U.S.D.I. Bureau of Land Management 2005; Ladyman 2006
WI	SNR	None	None	Newly documented in 2007 (*Horky #s.n.*, UWSP)	Robert W. Freckmann Herbarium, University of Wisconsin-Stevens Point 2012
WY	S2	None	Sensitive, Region 2	Four extant sites and one historical site in Bighorn National Forest, Yellowstone National Park, and possibly Medicine Bow National Forest. Rank recently downgraded from S1.	Fertig 2000a, 2000b; Ladyman 2006;l Heidel 2012

[1]SNR= Not Ranked; S1= Critically Imperiled; S2= Imperiled (NatureServe 2013)
[2]E= Endangered; T= Threatened

iled or critically imperiled in four of the eight states in which it occurs, including Michigan (Table 1). Reports of the species from Oregon and Maine have not been confirmed with specimens, and the taxon is not treated in recent floristic works encompassing those states (Ladyman 2006; Cook and Sundberg 2011; Haines 2011; C. S. Campbell, pers. comm., 7 February 2012).

Until recently, the status of *Rubus acaulis* in Michigan was poorly known. The species was first discovered in the state in 1976, and no new sites were documented until the mid-2000s (Voss 1985; MNFI 2013a). Recent discoveries and collections necessitate a review of our current understanding of the distribution, ecology, and conservation status of *R. acaulis* in Michigan. This paper aims to (1) provide updated collection data to inform the conservation and listing status of *R. acaulis* in Michigan; (2) clarify the distribution and ecology of *R. acaulis* in Michigan to aid survey and conservation efforts; (3) discuss the challenges as-

sociated with the conservation of a boreal relict species, particularly in the context of climatic warming; and (4) suggest avenues for monitoring and research.

COLLECTION HISTORY AND DISTRIBUTION

Rubus acaulis was first discovered in Michigan in 1976 by Charlotte Taylor while exploring a peatland in Schoolcraft County known colloquially as Shingleton Bog (C. M. Taylor, pers. comm., 11 March 2013). The first collections from this site date to May 1977 (*Henson #680, Henson #682*, MICH). Following its initial discovery, 26 years passed before a second location was documented, this one a partially forested peatland in western Luce County, north of Danaher Junction (*MacKinnon #03-283*, MICH). Since that time, the first author and colleagues have documented the species from six additional peatland sites in Chippewa, Luce, Schoolcraft, and Marquette counties between 46.1304° N and 46.3538° N latitude and 87.2521° W and 85.0236° W longitude (MNFI 2013a; Figure 2). Most Michigan occurrences are located in the Seney Sand Lake Plain ecoregion (Seney-Tahquamenon Sand Plain in Omernik and Bryce 2010) that

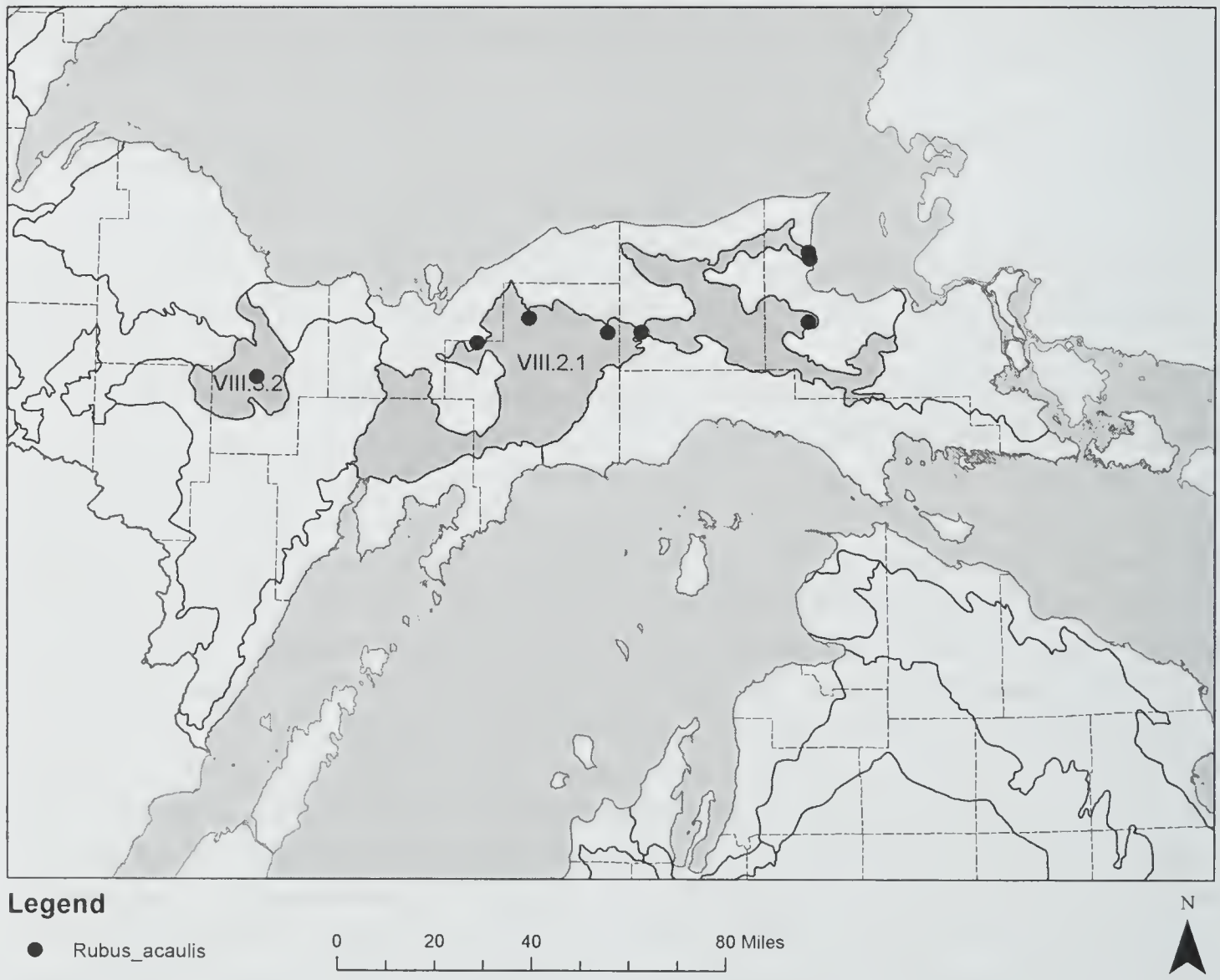

FIGURE 2. Known occurrences of *Rubus acaulis* in Michigan. VIII.2.1 = Seney Sand Lake Plain Ecoregion; VIII.3.2 = Gwinn Ecoregion (Albert 1995).

encompasses much of the central eastern Upper Peninsula, including portions of Chippewa, Mackinac, Luce, Schoolcraft, Alger, and Delta counties (Albert 1995; Figure 2). This ecoregion is characterized by expansive peatlands developed over poorly drained outwash and lacustrine sands associated with former embayments of Glacial Lake Algonquin (Albert 1995; Jerome 2006). Although Glacial Lake Algonquin last covered this area between 11,000 and 10,000 Y.B.P., the peatlands apparently established more recently (beginning approximately 5,000 to 3,000 Y.B.P.) following a climatic shift to cooler, wetter conditions (Futyma 1982; Futyma and Miller 1986; Madsen 1987; Brugam and Johnson 1997).

At the time of the General Land Office (GLO) surveys in the mid-1800s, the Seney Sand Lake Plain supported approximately 190,000 ha (470,000 ac) of swamp forest dominated by *Thuja occidentalis* (northern white-cedar) and other conifers, and 83,000 ha (200,000 ac) of open peatland (Comer et al. 1995). Although logging and attempts at drainage have altered wetlands in the ecoregion, the peat deposits currently support extensive mixed conifer swamps dominated by *T. occidentalis*, *Larix laricina* (tamarack), and *Picea mariana* (black spruce) (Albert 1995). Open peatlands, including groundwater-fed fens and weakly minerotrophic to ombrotrophic bogs and muskegs, also remain common, particularly on the broadest peat deposits southwest of Seney and northeast of Newberry (Comer et al. 1995). *Rubus acaulis* has been documented from seven such open peatland sites in the Seney Sand Lake Plain, at elevations ranging from 190 m (620 ft) near the mouth of the Tahquamenon River in Chippewa County to 254 m (830 ft) in the north-central portion of the ecoregion (Figure 2).

In 2010, the first author collected *Rubus acaulis* from an open peatland known as the Cyr Swamp in south-central Marquette County that occupies much of the poorly drained outwash plain in the Gwinn Ecoregion (included within the Menominee Drumlins and Ground Moraine Level IV ecoregion of Omernik and Bryce 2010). This is the first documented site for the species outside of the Seney Sand Lake Plain, and also the westernmost (87.2521° W), southernmost (46.1304° N), and highest elevation (approximately 330 m, or 1080 ft) documented site for *R. acaulis* in Michigan. West of the Gwinn Ecoregion, higher-relief landforms developed over ancient metamorphic and igneous bedrock restrict the development and scale of minerotrophic peatlands, limiting potential habitat for *R. acaulis*. However, *R. acaulis* has been documented from forested peatlands in Douglas County, Wisconsin and St. Louis County, Minnesota, suggesting the possibility that the species may occur in similar habitats in western Upper Michigan (Smith 2008; Robert W. Freckmann Herbarium, University of Wisconsin-Stevens Point 2012).

ECOLOGY

In Michigan, *Rubus acaulis* occurs in minerotrophic shrub- and sedge-dominated peatlands, corresponding to several vegetative associations described and classified in the United States National Vegetation Classification (USNVC) (NatureServe 2013) (Table 2). The Michigan Natural Features Inventory (MNFI)

TABLE 2. United States National Vegetation Classification (USNVC) Ecological Associations associated with *Rubus acaulis* populations in Upper Michigan (NatureServe 2013).

USNVC Ecological Association Unique Identifier	USNVC Ecological Association Common Name
CEGL002494	Bog Birch – Leatherleaf Rich Fen
CEGL002495	Bog Birch – Shrubby-cinquefoil Rich Boreal Fen
CEGL002500	Boreal Sedge Rich Fen
CEGL005226	Tamarack Scrub Poor Fen
CEGL005227	Bog Birch – Willow Shore Fen

classifies all eight *R. acaulis* sites as one of three fen types: patterned fen, northern fen, and poor fen (Kost et al. 2007; MNFI 2013a). Patterned fens appear to be particularly important habitat for *R. acaulis*, supporting five of the eight documented populations in Michigan. These peatlands are named for their so-called "ribbed" appearance associated with the presence of alternating peat ridges (strings) and hollows (flarks) oriented along the contours of the peatland slope, perpendicular to the flow of groundwater (Kost et al. 2007; Slaughter and Cohen 2010) (Figure 3). Patterned fens develop in "water tracks," which are concave- or flat-surfaced zones of drainage that channel sheet flow across peatland surfaces (Glaser 1992a; Price and Maloney 1994). Water tracks begin as narrow channels in swamp forest or other wetland communities at the upslope margins of the open peatlands and coalesce and widen downslope (Glaser 1992a). Strings and flarks are thought to develop due to the repeated inundation of depressions on the surface of the peatland, which causes their eventual expansion and coalescence across the contours of the peatland slope (Foster et al. 1983; Foster and King 1984; Glaser 1992b; Price and Maloney 1994; Quinton and Roulet 1998). Although patterned fen is known from only 20 sites in Michigan and the community is considered imperiled in the state (Kost et al. 2007), many occurrences are expansive, and the statewide acreage currently occupied by high-quality patterned fen is approximately 15,600 ha (38,500 ac, or 60 square miles) (MNFI 2013a).

Within patterned fens, *Rubus acaulis* occurs primarily in hummocky areas that support *Sphagnum*, ericaceous shrubs, and wetland conifers. This habitat occurs in the ecotone between swamp forest and open fen meadow and in "tails" of woody vegetation that occur either as extensions of the swamp forest within the fen meadow or immediately downslope of isolated dune ridges, where woody vegetation develops in response to impeded water flow and increased nutrient inputs from the adjacent mineral soils (Heinselman 1963, 1965, 1970; Glaser et al. 1981; Crum 1988; Glaser 1992a, 1992b, 1992c; Cohen et al. 2009; MNFI 2013a). Within the patterned water tracks that support fen meadow, *R. acaulis* is concentrated on the strings, where it is typically rooted in *Sphagnum* spp (Figure 3). These mosses create a thin, highly acidic (pH= 4.5–5.5), fibric substrate over peats that are otherwise less acidic (pH= 6.0-7.0), derived from sedges, and more decomposed. *R. acaulis* also occurs occasionally in mucky depressions and in flarks that lack *Sphagnum* mosses, but the species appears to be less widely distributed and less abundant in these habitats (MNFI 2013a). The relative impor-

FIGURE 3. Poor fen in Marquette County, Michigan. This extensive poor fen supports a very limited area of shrub-dominated strings (foreground) and sedge-dominated flarks (middle) where sheet flow is impeded by scattered dune ridges covered in pine forest (background). *Rubus acaulis* occurs primarily on *Sphagnum* hummocks within this fen. (Photograph by Bradford S. Slaughter, 12 September 2010.)

tance of *Sphagnum* hummocks and strings for *R. acaulis* may be associated with the water-holding capacity of hummock-forming *Sphagnum* species (Hájek and Beckett 2008), which may buffer this microhabitat from the impacts of drought.

The other three *Rubus acaulis* sites are classified as either northern fen (two sites) or poor fen (one site). Northern fens and poor fens lack strings and flarks, but are otherwise characterized by vegetation structure and plant species composition similar to that expressed in patterned fen (MNFI 2013a). The northern fen sites are dominated by fine-leaved sedges and minerotrophic shrubs with limited importance of *Sphagnum* and ericaceous shrubs and occur on slightly acid to mildly alkaline (pH 6.5–7.5) sedge- or shrub-derived peats (Kost et al. 2007; Cohen and Kost 2008a; MNFI 2013a). The single *R. acaulis* site characterized as a poor fen supports extensive areas of *Sphagnum* and ericaceous shrubs with lower importance of fine-leaved sedges and minerotrophic shrubs and occurs on medium acid to slightly acid (pH 5.5–6.5) sedge- and shrub-derived peats (Kost et al. 2007; Cohen and Kost 2008b; MNFI 2013a). Although northern fen and poor fen differ in vegetation dominance and soil properties, *R. acaulis* tends to occupy the same *Sphagnum* hummock microhabitat in both communities (MNFI 2013a). The species occurs with lower frequency and at lower density in sedge-

TABLE 3. Vascular plant taxa that occur at seven or eight of eight documented Michigan *Rubus acaulis* sites. Taxa that occur at all eight sites indicated in **bold**. Data sources: MNFI (unpublished data); Schultz (1987); MacKinnon (2005).

Tree	Shrub	Herb
Larix laricina	*Alnus incana*	*Anemone quinquefolia*
Picea mariana	***Andromeda glaucophylla***	*Calamagrostis canadensis*
Pinus strobus	***Aronia prunifolia***	*Carex exilis*
Thuja occidentalis	***Betula pumila***	***Carex lasiocarpa***
	Chamaedaphne calyculata	*Carex livida*
	Dasiphora fruticosa	***Cladium mariscoides***
	Lonicera villosa	*Comarum palustre*
	Myrica gale	*Coptis trifolia*
	Rhamnus alnifolia	***Doellingeria umbellata***
	Rhododendron groenlandicum	*Drosera rotundifolia*
	Vaccinium oxycoccos	***Equisetum fluviatile***
		Iris versicolor
		Linnaea borealis
		Maianthemum trifolium
		Muhlenbergia glomerata
		Oclemena nemoralis
		Osmunda regalis
		Pogonia ophioglossoides
		Pyrola americana
		Rhynchospora alba
		Sarracenia purpurea
		Solidago rugosa
		Solidago uliginosa
		Trichophorum alpinum
		Trichophorum cespitosum

dominated areas within these fen systems. Of note, *R. acaulis* has not been documented from poor fens weakly influenced by groundwater (pH< 5.5), nor has it been observed in the moderately to strongly alkaline (pH 8.0–8.5), marly northern fens that are especially characteristic of the Niagara Escarpment region of the eastern Upper Peninsula (Albert 1995; MNFI 2013a).

Vegetative associates of *Rubus acaulis* in Michigan are consistent across its three peatland habitats. A total of 22 taxa occur at all *R. acaulis* sites, and 40 taxa occur in at least seven of the eight documented sites (Table 3). Stunted individuals of *Larix laricina*, *Picea mariana*, *Thuja occidentalis*, and *Pinus strobus* (white pine) are characteristic of all *R. acaulis* sites. Fen hummocks are typically dominated by ericaceous shrubs such as *Andromeda glaucophylla* (bog rosemary), *Chamaedaphne calyculata* (leatherleaf), *Rhododendron groenlandicum* (Labrador-tea), and *Vaccinium oxycoccos* (small cranberry), as well as shrubs indicative of more minerotrophic conditions, such as *Betula pumila* (bog birch), *Dasiphora fruticosa* (shrubby cinquefoil), *Myrica gale* (sweet gale), and *Rhamnus alnifolia* (alder-leaved buckthorn). Characteristic ground layer associates on hummocks include *Anemone quinquefolia* (wood anemone), *Carex lasiocarpa* (wiregrass sedge), *Doellingeria umbellata* (tall flat-topped white aster), *Equisetum fluviatile* (water horsetail), *Maianthemum trifolium* (false mayflower), *Muhlenbergia glomerata* (marsh wild-timothy), *Oclemena nemoralis* (bog aster), *Os-*

munda regalis (royal fern), *Pyrola americana* (round-leaved pyrola), *Sarracenia purpurea* (pitcher-plant), *Solidago uliginosa* (bog goldenrod), *Trichophorum alpinum* (Alpine bulrush), and *T. cespitosum* (tufted bulrush). In depressions and flarks, *R. acaulis* occurs with several additional herbaceous associates, including *Carex livida* (livid sedge), *Cladium mariscoides* (twig-rush), *Iris versicolor* (wild blue flag), and *Rhynchospora alba* (white beak-rush). One other notable associate is *Rubus pubescens* (dwarf raspberry), a widespread species that differs from *R. acaulis* in its smaller, white flowers, pedicels that bear at least a few glands, and sharply acute to acuminate leaflets (Voss and Reznicek 2012). This species occasionally hybridizes with *R. acaulis*, producing *R.* x*paracaulis*, which has been collected from Michigan (Henson 682; MICH; determination E. G. Voss). In total, approximately 220 vascular plant taxa have been documented from Michigan peatlands that support populations of *R. acaulis* (MNFI 2013b).

The only quantitative data on vegetative associates of *Rubus acaulis* in Michigan was collected by Schultz (1987) at Shingleton Bog, the first documented site for dwarf raspberry in Michigan. In all three fen openings studied by Schultz, *Trichophorum cespitosum* was the most or secondmost important vascular plant associate (Table 4). Other important species included *Anemone quinquefolia*, *Andromeda glaucophylla*, *Solidago uliginosa*, *Vaccinium oxycoccos*, *Muhlenbergia glomerata*, *Oclemena nemoralis*, *Rhododendron groenlandicum*, *Dasiphora fruticosa*, and *Maianthemum trifolium* (Table 4). *Sphagnum* spp. provided at least 20% average cover in all three study sites; only *Sphagnum* mosses and *Trichophorum cespitosum* averaged greater than 10% cover in all three fen openings (Table 5). Although most of the aforementioned taxa are broadly distributed in Upper Michigan wetland communities, their co-occurrence indicates potential habitat for *R. acaulis* in the Seney Sand Lake Plain Ecoregion.

Specimen labels and MNFI field survey data do not identify bryophyte associates of *Rubus acaulis* to the species level. In general, strings (in patterned fens) and hummocks within minerotrophic fen systems support several *Sphagnum* species, including *S. angustifolium*, *S. capillifolium*, *S. magellanicum*, *S. re-*

TABLE 4. Ten most important vascular and non-vascular plant associates in *Rubus acaulis* quadrats, Shingleton Bog, ranked by Importance Value (IV = relative frequency + relative dominance). Adapted from Schultz (1987).

Big Bog		**South Bog**		**Section 12 Bog**	
Species	**IV**	**Species**	**IV**	**Species**	**IV**
Trichophorum cespitosum	121	*Sphagnum* spp.	132	*Trichophorum cespitosum*	144
Rubus acaulis	102	*Trichophorum cespitosum*	103	*Sphagnum* spp.	125
Rhamnus alnifolia	88	*Rubus acaulis*	102	*Solidago uliginosa*	103
Picea mariana	72	*Anemone quinquefolia*	101	*Rubus acaulis*	102
Sphagnum spp.	71	*Vaccinium oxycoccos*	84	*Andromeda glaucophylla*	102
Dasiphora fruticosa	70	*Alnus incana*	71	*Anemone quinquefolia*	101
Andromeda glaucophylla	69	*Rhododendron groenlandicum*	69	*Vaccinium oxycoccos*	100
Maianthemum trifolium	69	*Andromeda glaucophylla*	67	*Lonicera villosa*	87
Oclemena nemoralis	67	*Oclemena nemoralis*	67	*Muhlenbergia glomerata*	84
Solidago uliginosa	67	*Viola* spp.	67	*Drosera rotundifolia*	83
Muhlenbergia glomerata	67				

TABLE 5. Ten vascular and non-vascular plants with the highest percent cover in *Rubus acaulis* quadrats, Shingleton Bog. Adapted from Schultz (1987).

Big Bog		**South Bog**		**Section 12 Bog**	
Species	**IV**	**Species**	**IV**	**Species**	**IV**
Trichophorum cespitosum	38	*Sphagnum* spp.	32	*Trichophorum cespitosum*	44
Sphagnum spp.	21	*Trichophorum cespitosum*	19	*Sphagnum* spp.	25
Gaultheria hispidula	6	*Dasiphora fruticosa*	5	*Picea mariana*	5
Picea mariana	6	*Alnus incana*	5	*Thuja occidentalis*	5
Thuja occidentalis	6	*Picea mariana*	4	*Solidago uliginosa*	3
Rhamnus alnifolia	4	*Ilex verticillata*	5	*Lonicera villosa*	3
Dasiphora fruticosa	4	*Viburnum cassinoides*	3	*Carex exilis*	2
Trichophorum alpinum	3	*Rubus acaulis*	2	*Rubus acaulis*	2
Maianthemum trifolium	2	*Carex exilis*	2	*Andromeda glaucophylla*	2
Rubus acaulis	2	*Prunella vulgaris*	2	*Larix laricina*	2
Andromeda glaucophylla	2	*Rhododendron groenlandicum*	2	*Menyanthes trifoliata*	2
Carex stricta	2	*Sarracenia purpurea*	2		
		Thuja occidentalis	2		
		Carex stricta	2		
		Cirsium spp.	2		

curvum, and occasionally *S. warnstorfii* (Slaughter and Cohen 2010). The upper portions of strings and hummocks, which can be highly acidic due to isolation from groundwater, may support *S. fuscum* and *Polytrichum juniperinum* (juniper polytrichum moss) (Wheeler et al. 1983; Crum 1988). Bryophytes are typically of low importance in flarks and depressions, but are represented by several species, including *Aulacomnium palustre*, *Calliergon trifarium*, *Campylium polygamum*, *C. stellatum*, *Dicranum undulatum*, *Drepanocladus* spp., *Polytrichum strictum*, *Scorpidium scorpioides*, several sphagnum mosses (e.g., *Sphagnum angustifolium*, *S. cuspidatum*, *S. majus*, *S. magellanicum*, *S. papillosum*, *S. recurvum*, *S. subsecundum*, and *S. teres*), and several liverworts (including *Calypogeia* spp., *Cephalozia* spp., *Kurzia setacea*, and *Mylia anomala*) (Wheeler et al. 1983; Madsen 1987; Crum 1988; Janssens 1992). Further surveys are needed to document microhabitat-specific bryophyte associates of *R. acaulis* in Michigan.

CONSERVATION STATUS

Following its discovery in Michigan in 1976, *Rubus acaulis* was assigned threatened status in the 1980 listing of state endangered and threatened plant species. Subsequent to its discovery, *R. acaulis* was listed as a sensitive species in the Hiawatha National Forest within USFS Region 9 (USDA Forest Service, Eastern Region 2002). Over 20 years passed without any new sites being discovered, and the species was upgraded to endangered status in 1999. Since that time, several additional populations of *R. acaulis* have been documented in Upper Michigan, and a total of eight occurrences are currently tracked by MNFI (MNFI 2013a). All of these populations appear to have good to excellent viabil-

ity based on area of occupancy, population density, occurrence in relatively undisturbed habitats, and other factors (MNFI 2013a). The first documented population in Schoolcraft County occurs within the Shingleton Bog Candidate Research Natural Area (cRNA) within the Hiawatha National Forest. Establishment of this area as a RNA would provide formal protection for this *R. acaulis* population and its fen habitat. A second population of *R. acaulis* occurs in the eastern unit of the Hiawatha National Forest. A third population is partly protected within Tahquamenon Falls State Park, and extends into the adjacent Lake Superior State Forest (LSSF). Four other populations occur within LSSF and adjacent commercial forest lands, and one population has been documented from the Escanaba River State Forest (ERSF) (MNFI 2013a). Although the largest and presumably most viable *R. acaulis* populations occur within LSSF and ERSF, only one of these sites (Creighton Marsh) has received a special conservation designation as an Ecological Reference Area (Cohen et al. 2009), and efforts to provide additional measures of protection to the other sites have proven controversial (Casperson 2013; Garmon 2013).

One of the potential challenges to long-term conservation of *Rubus acaulis* in Michigan is poor fruit set and, presumably, low levels of outcrossing (Ladyman 2006). Over a three year span, the second author monitored *R. acaulis* populations in Shingleton Bog out of concern for the potential of a newly constructed logging road to disrupt water flow within the fen and negatively impact the habitat (Schultz 1987, 1988, 1990). Over that three year-span, the number of stems, average number of leaves per stem, percent cover, and number of fruits or dried flowers showed little variability in 18 permanent 1 m^2 quadrats (Schultz 1990). Few fruits were observed in any year, consistent with the documentation of scarce fruit production at the other Michigan sites (MNFI 2013a). Flower and especially fruit production also appears to be poor in the western United States, suggesting that *R. acaulis* reproduces primarily through cloning at the edges of its range (Spackman et al. 1997; Fertig 2000b; Ladyman 2006). Clonal reproduction is a life history strategy that has been demonstrated for several other edge-of-range plant species, and appears to be associated with a variety of genetic and environmental factors (Dorken and Eckert 2001; Beatty et al. 2008). Inferences from studies on *R. arcticus* ssp. *arcticus* suggest the lack of fruiting may be due to the presence of triploid populations, a preponderance of self-incompatible clones, or a lack of pollination (presumably by honeybees and/or bumblebees) (Tammisola and Ryynänen 1970; Ladyman 2006).

Rubus acaulis is a relict species that occupies peatland habitats that are expected to be sensitive to climatic warming and associated changes in water balance and nutrient cycling (Galatowitsch et al. 2009; Kost and Lee 2011). A warmer climate is expected to cause an increase in vascular plant cover, particularly that of ericaceous shrubs, as a result of lowered water tables and altered nutrient cycling (Weltzin et al. 2003; Galatowitsch et al. 2009; Essl et al. 2012; van Dijk et al. 2012; Bragazza et al. 2013; Jassey et al. 2013). *Sphagnum* cover, on the other hand, is expected to decline. Because Michigan populations of *R. acaulis* occur in close association with *Sphagnum*, a reduction of cover and vigor of these mosses will likely have detrimental impacts to the species. In addition, warmer, drier conditions will likely lead to more frequent and severe peatland

wildfires that threaten to reduce moss cover and organic soils and alter peatland ecology and vegetation (Galatowitsch et al. 2009). Galatowitsch et al. (2009) suggest several climate change adaptation strategies to reduce the potential negative impacts of climatic warming on peatland habitats, including the prohibition of drainage projects in the vicinity of peatlands, the prohibition of groundwater withdrawals in recharge areas of fens, and the control of peat fires. Regardless of actions taken to mitigate the effects of climate change on peatland ecology, the long-term persistence of *R. acaulis* in Michigan appears to be at risk. Canadian climate change models for *R. acaulis* put Upper Michigan out of the climatic range of the taxon under 19 of 20 climate projection scenarios by 2040 and in all 20 scenarios by 2070 (Natural Resources Canada, Canadian Forest Service 2011).

Based on the range of the species, area of occupancy, number of occurrences, population sizes, condition of habitat, and threats, including climate change (NatureServe 2013), the Endangered Species Technical Committee for Plants should consider downgrading the conservation status of *R. acaulis* in Michigan from S1 (critically imperiled) to S2 (imperiled).

SUGGESTIONS FOR FUTURE WORK

Additional surveys for *Rubus acaulis* should be conducted throughout Upper Michigan. Three particular areas are likely to yield additional populations: (1) the vicinity of Seney National Wildlife Refuge, encompassing much of northern and eastern Schoolcraft County; (2) the peatlands of northwestern Chippewa County and northern and eastern Luce County, in the vicinity of Trout Lake, Eckerman Corner, Hulbert, Newberry, McMillan, and Paradise; and (3) the vicinity of Cyr Swamp in Marquette County, south of Gwinn and primarily east of the Escanaba River, with a smaller area of shrub-dominated fen west of the river. Potential habitat in all three areas is extensive. High resolution aerial imagery of this entire region is widely available and can be used to target likely fens within these areas. The preponderance of boreal relict species in the Keweenaw Peninsula and especially Isle Royale (Given and Soper 1981; Marr et al. 2009) and presence of fen habitats (Slavick and Janke 1987; Cohen 2009) suggests at least a fair probability that *R. acaulis* may occur in one or both of these locales, as well. Although *R. acaulis* may occur elsewhere in western Upper Michigan, its typical fen habitat is less widely distributed and much less extensive in this region. At each newly documented *R. acaulis* site, detailed lists of vascular plant associates and especially non-vascular plant associates (hornworts, liverworts, and mosses) should be recorded to improve our understanding of *R. acaulis* habitat in Michigan.

Monitoring of *R. acaulis* and its habitat should be implemented to track changes in population size, plant vigor, and fecundity and to document changes in organic soils, hydrology, and species composition and vegetative structure of the peatlands it occupies. Because *R. acaulis* in Michigan is a relict, edge-of-range species, it is likely to be especially sensitive to climate change and associ-

ated changes in its peatland habitats. Therefore, its population dynamics may serve as a good indicator of the health of several of the largest peatland ecosystems in Upper Michigan. Although *R. acaulis* is considered secure globally, these peripheral populations may possess genetic distinctiveness that may prove important to the overall conservation of the taxon, particularly with regard to adaptive potential in the face of climatic warming (Beatty et al. 2008). With this in mind, population and genetic studies that address the viability and genotypic richness of *R. acaulis* populations in Michigan are suggested in order to better determine the long-term viability of this species in the state.

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NOTEWORTHY COLLECTIONS

Michigan

Mikania scandens (L.) Willd.
Asteraceae
Climbing Hempweed

Previous knowledge. *Mikania scandens* is a vine found in wetlands of the eastern United States (USDA). It ranges from Florida to Maine and west to Texas and is considered a noxious weed in Hawaii. It was first reported from Michigan by C.D. McLouth (1896). The plant was brought to McLouth's attention in 1894, and that September, he observed it growing in the wetlands near the mouth of the Muskegon River in what is now Muskegon State Game Area (MSGA), Muskegon County. Inquiries to locals in the area allowed McLouth to conclude that *M. scandens* had been present since at least the mid-nineteenth century. This has remained the only report of *M. scandens* in Michigan up to the present (Reznicek et al. 2011). The nearest known populations are about 200 kilometers to the south in northern Indiana (Swink & Wilhelm 1994). Attempts to relocate this species in the areas described by McLouth have been unsuccessful, leading to this species being designated as extirpated from Michigan (Reznicek et al. 2011).

Significance of the Report. This is a significant find as this is the first report of this species in Michigan since it was originally reported by McLouth in 1896. I observed three populations, all roughly within 2 kilometers of each other. Only one of the populations was surveyed and there appeared to be about 50 healthy individuals setting seed at the coordinates provided on the collection label. The other populations were in remote areas and occurred in dense *Cephalanthus occidentalis* thickets and only a few individuals were observed at each location. More thorough surveys are needed in the areas between Cedar Creek and the Muskegon River to accurately describe the condition of the metapopulation.

Diagnostic characters. *Mikania scandens* is a climbing herb of floodplains (Fig. 1), often twining up *Cephalanthus occidentalis* to heights of 3.0 m and occasionally forming mats over *Phalaris arundinacea* and *Leersia oryzoides*. The leaves are oppositely arranged at swollen nodes, deeply cordate, palmatly veined, and toothed. The flowers are small, pale-purple to white, and form loose corymbs born on axillary peduncles (MNFI 2007). Collected specimens were observed to be blooming throughout September. *M. scandens* may be mistaken for *Ageratina altissima* as the flowers are somewhat similar. However, *M. scandens* is a vine whereas *A. altissima* is a stout upright herb.

Specimen Citation. *Mikania scandens* (L.) Willd. Muskegon Co., Michigan: Muskegon State Game Area. 5 Miles SSW of Twin Lake. Lat. & Long.: 43° 17′ 34.2 N, 86° 07′ 41.1″W. Between Cedar Creek and the Muskegon River along the margins of openings in the *Acer saccharinum* dominated floodplain forest.

FIGURE 1. *Mikania scandens* in Muskegon State Game Area, MI. Photo taken by Jesse Lincoln on Oct 2, 2012.

Primarily climbing on *Cephalanthus occidentalis* and *Fraxinus pennsylvanica*. There seems to be a strong association of *M. scandens* and *C. occidentalis*. Also found occasionally forming mats atop *Phalaris arundinacea*. Highly localized but somewhat abundant. The majority of individuals observed were fruiting and scenesent at the time of collection, 3 October 2012. Jesse M. Lincoln; (MICH).

ACKNOWLEDGMENTS

I would like to thank Dr. Tony Reznicek for his assistance editing this paper and for confirming the identity of *Mikania scandens* in the field. Todd Barkman also reviewed the article and provided helpful comments for improvements. Valerie Campbell assisted in the collection of samples and her efforts were appreciated.

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BOOK REVIEW

Simmons, Eric. 2009. *Darwin Slept Here*. The Overlook Press. New York, NY. 258 pp. ISBN 978-1-59020-220-3 $24.00. (Hardbound)

If a person is given a pairing game and they have placed Charles Darwin's name in the mix, most people would pair Darwin's name with evolution. I know I would. Because of Darwin's theory of evolution by natural selection, his name has become synonymous with evolution. People who saw me reading this book thought that I was reading about Darwin's theory because the title had his name on it. However, after reading the book, I have a glimpse of the real Darwin most people do not see. Most photos depicts Darwin as an old man, with "Santa Clause beard", quiet, wrinkled and maybe boring. But who is Darwin, really? Was he always this "old man" or was he once a vibrant young man ready to face the unknown?

Eric Simmons, a young man from San Francisco decided to journey and experience first-hand how a young explorer Darwin might feel. He travelled to South America and he compared his experience with that of Darwin's, based on his diary notes: "The Voyage of the Beagle". Instead of unravelling the escapade of an "old wrinkled man", Simmons discovered the escapades of a young, fun-loving Darwin whose adventures were exhilarating also to Simmons himself. Simmons went to every place that Darwin visited based on his records and walked where he perceived Darwin walked. Simmons attempted to see what Darwin would have seen if he was looking at the same glorious views. Like Darwin, the author viewed many things; from rheas to a beach filled with fossils in Port San Julian. Reading this book, Simmons' eyes become our eyes as to what Darwin saw, but instead of us seeing it physically, we experience it through his words. Simmons described the side of Darwin that most people never see, the adventurous young man who goes places to learn. A most interesting part is that Simmons exhibited the same adventurous spirit that Darwin had.

The book was divided into three parts: exploration of the industrialized South America where Simmons explored the now changed South America, revolution of the people where the author focused on the people of South America of present compared to the people during Darwin's era, and Darwin's discoveries where Simmons looked at the most important things that Darwin discovered while exploring South America. Each of these parts gives an idea as to what differences Simmons experienced as compared to Darwin's time. At the end of the book, Simmons shares his moving experience of sleeping at the same house where Darwin slept and how he imagined the difference between his time and Darwin's time. The contrast of time may have been very different but the experiences that Simmons and Darwin experienced were irreplaceable, regardless of the time difference.

So who was the young Darwin? Read this book and it will give you an idea of who young Darwin was with less facial hair and how passionate Darwin was

about his travels in South America discovering new species and places. Simmons' book will give you a detailed and exhilarating experience that will keep you wanting to know what happens next. This book will show you the different side of Darwin, the man usually depicted as "the man with the long-white beard".

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On the cover: No longer extirpated! *Mikania scandens* in Muskegon State Game Area, MI where it has been rediscovered more than 100 years after its original discovery in the state. Photo taken by Jesse Lincoln on Oct 2, 2012.